Detailed Project Report

National Mission

on

Data Analytics and Predictive Technologies

DAPT 2020

Indian Institute of Technology

(Banaras Hindu University)

Varanasi 221005; Uttar Pradesh

आचार्य प्रमोद कुमार जैन
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Foreword

Information engineering and data interpretation indeed heralds a new era of technological advancement. Indeed, as the World Economic Forum assesses, "Data is the new currency".

In this age, when man, machine, methods and materials, are getting integrated by seamless interconnectivity, the newly emerging field of "Data Analytics and Predictive Technologies" (DAPT) has indeed the potential to produce transformative technologies and novel solutions for the societal, national and global needs across all sectors and walks of life.

Previously, due to our checkered history, we could not take advantage of the Eurocentric Industrial Revolution of the 19th century, rather India's market was the main fuel that forged that revolution there. However, the 21st century is a great equalizer. In the current information era, India stands to take full advantage of computational technology and employment revolution, as the country adds a trillion dollar to its economy every couple of years. Standing at this juncture we can awe at the scope that DAPT, and the related A.I. and M.L. areas has to offer to our people.

The application of DAPT to societal betterment is limitless, being spread over all domains: Communication, Transportation, Energy, Defence, and Healthcare. It is indeed that in these DAPT domain applications, one needs to critically focus on bringing innovative engineering methodology and a whole range of processes and products along with skilled human resources, productive entrepreneurial ecosystem and transnational collaborations.

It is indeed a golden opportunity for Indian academics and technologists to usher in leadership in the country's industrial ecosystem and entrepreneurship. Indeed, we have to persevere to make India a leading player to catalyse innovative translation and solutions embedded with DAPT, across all disciplines of science, technology, medicine, and commerce, as well as the social, financial and industrial sectors. This, by all means, is a herculean challenge, and there is needed the creation of the right infrastructure and resources to deliver state-of-the-art solutions both locally and globally, and IIT(BHU) has rightfully decided to initiate the "National Mission on Interdisciplinary Data Analytics and Predictive Technologies" (NM-DAPT).

I am glad that the detailed project report on the National Mission on Interdisciplinary Data Analytics and Predictive Technologies (NM-DAPT) has been brought out by IIT(BHU) at this strategic phase of disruptive technology advancement. It covers not just R&D, but also takes education, translational or skill development, and entrepreneurship in full spirit.

I am certain that the DPR will help guide us to create an ecosystem for DAPT with a firm implementation strategy as well. It is exciting to behold a seminal enthusiasm and synergy among the IIT(BHU) faculty members for India's technology leadership in the area.

(Pramod Kumar Jain)

EXECUTIVE SUMMARY

Motivation

The Indian Institute of Technology (Banaras Hindu University) is the country's oldest multi-disciplinary engineering institute, which has dedicated itself to the nation for the last 100 years. IIT(BHU)'s mandates are to identify new and emerging areas in the context of national development goals and to initiate timely interventions for fostering such areas for creating strategic leadership. The area of Data Analytics and Predictive Technologies (DAPT) has been identified as one of the emerging fields whose progress will add significant impact on a number of verticals of the economy, such as, Telecommunications, Power, Road Transport and Highways, Defence Research and Development, and Health and Family Welfare. Further relevant areas are urban smart city initiatives, including city-wide water distribution, waste management, air quality monitoring and control, as well as manufacturing and governance at national and international scales.

This Detailed Project Report (DPR) on National Mission on Data Analytics and Predictive Technologies (NM-DAPT) presents an overview of DAPT in general, outlining the importance of disruptive innovations for the modernisation of socio-technical systems and services. The activities envisioned under this mission will provide a great fillip to Indian manufacturing and societal betterment, via the development of new protocols, inventions of novel products/processes and services. The endeavour shall catalyse the creation of skilled young engineers, researchers, technicians, and entrepreneurs, together with human resource at all levels, besides become a key contributor to realizing the vision of "Digital India", "Innovate in India", and "Make in India".

Scope

The DPR describes the underlying technologies and innovations, provides a preview of the many research issues, and discusses the national and international state-of-the-art approaches falling within the ambit of DAPT. The DPR contains a thorough analysis of the skill gaps, besides projecting the upcoming deluge of the demands for skilled human resource for the technological and scientific upliftment in all the sectors of industry and society. IIT(BHU) has traditional strengths in the development of smart sensors and system (SSS), development and Information and Communications Technology (ICT), as well as in the frontier disciplines of Materials science, Pharmaceutics and Bio Medical engineering, thereby harnessing diversified

application areas of interdisciplinary academic and research pursuits with deep scientific and analytical skills. IIT(BHU) is putting extensive thrust/application for its contribution towards modernisation of the country's core sector applications to Power, Manufacturing, Smart City, Mobility, Intelligent Networking, Armed forces response, and Healthy Wellbeing, for smart management of societal needs. These are the niche areas that will give India, our country, the advantage for achieving well timed leadership in the critical and emerging field of interdisciplinary data analytics and predictive technologies (DAPT).

The term “Data Analytics and Predictive Technologies (DAPT)” refers to the application of pattern recognition and inference engine as a smart decision support interface, to take timely decisions and deploy necessary actuation, in order to take holistic control of the real-life situations, either in online or off-line. Historically the first DAPT devices are from the age of ancient antiquity, such as the well-known Astrolabe and Antikythera calculators which were mechanical analog computers, developed around 500 BC in Asia minor, for aiding geographical surveying, navigation, and astronomical predictions.

DAPT’s earliest efforts to embed computers in physical situations to control and optimise the performance manifests in the world’s first long-range guided ballistic missile, V2, developed by Germany in the second world war during 1944. A later classical example of DAPT is from the 1970s, namely the embedded computer control of motor vehicle engines. Today, the term DAPT is used for systems involving intelligent pattern-recognition based decision support interfaces backed up by densely embedded sensors and actuators, interconnected by the Internet of Things (IoT), with computation occurring within the network, or at the edge, or in the cloud, for the purpose of observing, controlling, and optimising the performance of technical/societal/human systems, such as smart cities, smart energy grids, smart urban water networks, smart homes, smart farms or smart healthtech.

Functionalities

The term *smart* states that the corresponding system (or “vertical,” e.g., an urban transportation network, soldier protection, or healthcare diagnostics) is being enhanced by DAPT technology, the work on each vertical segment depends on the integration of several techniques, or “horizontals,” e.g., sensors, wireless communication, cloud computing, and data analytics). With the increasing need for efficient utilization of scarce resources such as water and energy, increasing urbanization, diagnostic/therapeutic delays, and increasing awareness of the impact

on the climate due to human activities, there is going to be increasing emphasis on "smartening up" our socio-technical systems, thereby requiring us to deploy the technology of DAPT.

The development of DAPT technologies requires fundamental scientific and mathematical advances in understanding of the system models, learning algorithms, wide variety of simple to deep networks, along with infrastructural components in terms of materials and devices, communications, computing and control over networks, along with machine vision, robotics, brain-machine interfaces for smart actuations, and neuroimaging platforms for cognitive and neuronal engineering.

Although the practical DAPT arena of the near future will be built on standard digital electronics, digital computing, and digital communications, rapid advances are happening in the technology areas of Quantum Computing, DNA Computing, Psychodynamic Affective Computing, and Brain-based Computing, where even the current computational paradigm will also change. To engage the expertise of our scientific community, to generate Human Resources for the future, and to develop our expertise and technologies in DAPT, the Mission envisages support from national research groups in all allied technologies as well.

National Mission on DAPT will empower National Critical Infrastructure (NCI) on intelligent breeds of innovative systems and will carry the potential to significantly impact daily lives as they form the basis for emerging and future smart services. Further, increased use of DAPT will also safeguard the new cybersecurity threats and would intelligently protect us from adverse consequences over the nation, as a country and the society as a whole.

Implementation

This DPR is a projection of the countrywide efforts being pursued by IIT(BHU) to assess the importance of DAPT as a technology, uncover the core R&D issues, assess the national status of the technology, and identify the national strengths and weaknesses for rolling out DAPT as a product for societal and industrial application, and for making India a forerunner, all across the globe, and particularly in Asia. This DPR also details the methods and structures to connect NM-DAPT with national developmental objectives, and aligning with the numerous National Missions of various Ministries of GOI, along with particular emphasis on the Sustainable Development Goals (SDG's) of the U.N. The DPR captures the aspirations of the citizens, assesses the present status of DAPT in terms of research or technology potential, and identifies various stakeholders across the sectors. It also carries a SWOT analysis, examines the legal

and policy framework, probes the market opportunities and the demand for workforce skills and presents the nationally-significant skill deficits.

NM-DAPT and the associated activities will be coordinated under one umbrella. The major sub-missions or programmes of the mission will be on (i) Technology Development, (ii) Establishment of Centres of Excellence, (iii) HRD & Skill Development, (iv) Innovation, Entrepreneurship & Start-up Ecosystem and (v) International linkages & collaborations; each further split into a number of components (projects/schemes).

The Mission will support research and innovation in academic and research institutions as well as industry and the venture business system, in areas such as those described earlier, leading to the development of DAPT technologies and applications. The NM-DAPT will support centers of Excellence (CoEs) in academic and research institutions across the country, in association with the industrial and financial sector, with significant economic and technical collaborations and with promises of technology adoption of the products so developed, for social upliftment. The CoEs will focus on the development of disruptive innovations in interdisciplinary, collaborative, and translational research to generate core domain knowledge and know-how. As per the mandate, IIT(BHU) will develop enterprise grade prototypes and proofs-of-concepts (PoC) following internationally standardised norms (e.g. IEEE, E.U.-ESO, FDA and others) and translate them into products, in conjunction with industry and start-ups leading to significant job creation and economic growth, across the country and the globe.

Components

Skill development, HRD and nurturing the start-ups through entrepreneurship programmes are also one of the goals of the NM-DAPT at IIT(BHU). Development and deployment of smart systems-of-systems, enhanced with DAPT applications, will require skilled human resources and faculty re-training at all levels, in technologies such as the intelligent IoT systems, design and deployment of low power wide area wireless sensor networks, machine learning and data analytics, together with security and privacy for the development and acceptance DAPT, both in the industries and by the society. At the deployment level, just as in the 1990s where there grew a need for digital communication network deployment technicians, there will emerge the need for the DAPT competent manpower for its strategic deployment and success in the form of products. There is a need to generate an advanced level of skilled HR to meet the emerging demands across the sectors. The NM-DAPT at IIT(BHU) will also develop and establish

research collaborations with international academic & research institutions for the advancement of interdisciplinary approaches in DAPT and associated research in the country.

The NM-DAPT is proposed to be implemented over five years. This DPR first provides an overview of DAPT as a major emerging technology and then details the objectives of the NM-DAPT programme, the implementation mechanisms, the legal framework, the budgetary requirements of the various sub-programmes, the measurable outcomes and the review mechanisms, and the mission management structure.

The technology innovation hub at IIT(BHU) aims to become a pioneer in leveraging the depth and breadth of interdisciplinary data analytics and predictive technologies to thoroughly support the national mission of a thriving digital India. The effect of these efforts would be manifested primarily in five domains of field of Telecommunications, Power, Road Transport and Highways, Defence Research and Development, Health and Family Welfare.

The implications of DAPT for these five domains of the economy are elucidated below.

(a) Telecommunications

The fourth industrial revolution is around the corner. So far, information technology had been the primary thrust/application, and all industrial and societal processes have been put on network. Much real-time and off-line data are being gathered. 'Trillion sensors and actuators' in any walk of life is the new paradigm. Computation and analytics are now the key for controlling physical systems and assured sensing and actuation is the new challenge. With such challenges, current networks that are based on best-delivery-efforts will no more be suitable. Even, we cannot afford to miss any single bit of information at the sensor side or the signal which has been sent to any single actuator. Each bit is essential and any mistake is unacceptable. Accordingly, whole new sets of new networking protocols with guaranteed-delivery of services will be needed. In the Cyber Physical System paradigm, it will require innovative approaches for the air interface providing massive scale transport over TCP – Ethernet IP and Time Sensitive Networks (TSN).

There is need for ultra-low latency, both in packet transfer and computation, leading to hybridisation of computer hardware with virtualised software based computation on the network interfaces, supporting massive 'softwarization', converging to IT methods and supporting absolute convergence of sensing and actuation well in tune with the data analytics and predictive technologies to impart intelligent automation. We are at the threshold of a new

revolution desiring holistic innovations and inventions to deliver such high-performance requirements. The proposed TIH for mounting a national mission on data analytics and predictive technologies (NM-DAPT) will lead India to produce innovations, inventions and new technology developments in the area of Intelligent Networks and Communication Systems, seeking state-of-the-art delivery of teaching, learning and manpower skilling, all across the globe, to design, deploy and run products and technologies for seamless adoption of DAPT.

(b) Power

The DAPT on Power is one the thrust/application areas recognized by the IIT (BHU) for its planned Centre on Data Analytics and Predictive Technologies. The DAPT at IIT (BHU) will undertake the technology development using DAPT for environment friendly, smart home automation with the system of Internet of Things (IoT)-activated smart devices that can be controlled remotely. The activities envisioned under the DAPT will provide a great impetus to India's Smart Cities Mission in terms of environmentally friendly, reliable, efficient, and IoT activated optimum power generation/flow and thus, setting up a DAPT based smart grid for smart homes and cities. The Mission will help in manufacturing via the invention of new products, services and the creation of skilled young human resource at all levels (technicians, researchers, scientists, and entrepreneurs).

The initiative of DAPT will become a key contributor to realizing the vision of "Digital India." An assessment of the estimated skill gaps is contained, besides the expected need for human resources in existing and new jobs across the infrastructural development of the country. The DAPT will be used for system-based power electronics involving embedded sensors, actuators, interconnected by IoT, with computing in the network for the purpose of optimising the socio-technical systems, such as smart energy grids for smart homes/cities. The development of DAPT will catalyse rigorous scientific advances in power processors, sensors, communications, and control over networks, for a variety of physical systems. In the DPR, the DAPT sector covers the culmination of a consultative process to assess the importance of the DAPT as a technology for smart cities mission, along with exploring the core R&D issues.

(c) Defence Research and Development

The proposed Detailed Project Report describes the requirements of technologies, need of the future research, and the forecasting of future events based on what happened in the past, using artificial intelligence or machine learning. The DPR also includes areas in which predictive

analytics may play an important role in the near future, specifically those pertaining to combat readiness like defence equipment and their parts replacement, effectiveness of a soldier in a real combat scenario, and medical attention requirement in a particular combat scenario etc. DPR is addressing crucial areas of defence like (a) border surveillance and role of drones and radars for surveillance, (b) microwave techniques for imaging, (c) stealth technique based on advanced polymer materials, (d) 5G for defence communications, (f) power systems for defence, (g) explosive detection, (h) smart sensors for soldiers and (i) and biosensors for safety and readiness of soldiers etc.

An assessment of the anticipated skill gaps will be studied, besides the expected need for human resources in existing and new job sectors. The Institute has strength in Information and Communications Technology, academic and research with deep scientific and analytical skills, and having extensive experience in core engineering such as Electrical and electronics, computer, transportation, materials and biomaterials, mechanical and pharmaceutic engineering. These are the advantages for the institute for achieving leadership in the critical and emerging field of Interdisciplinary Data analytics and predictive technology.

This DPR assesses the importance of DAPT as a defence technology, uncover the core R&D issues, assess the national status of the technology, and identify the national strengths and weaknesses. The consultative process also explored methods and structures to connect NM-ICPS with national developmental objectives with particular emphasis on Sustainable Development Goals (SDG's). The DPR captures the aspirations of both the defence forces as well as the general citizenry, and assesses the present status of DAPT in terms of research, technology potential and identifies various stakeholders across the sectors. It also carries a SWOT analysis, examines the legal and policy framework, assesses market opportunities and the demand for workforce skills and presents skill deficits in this novel endeavour towards enhancing the efficiency of the armed forces.

(d) Road Transport and Highways

Transportation plays a vital role in transporting goods and services from one location to another. The growing levels of road congestion and air pollution has led to the development of Intelligent Transportation System (ITS) that uses sensor data and communication technology to aid drivers, shippers and highway agencies to make fast, accurate and optimal decisions that reduce carbon footprints, minimize time lost due to congestion, while increasing safety,

reliability and efficiency. Sensors are becoming cheaper while the software that runs them as well as technology for collecting and managing data is ever improving.

There is an extensive opportunity for India to become a pioneer in applying ITS technologies and set an example especially for developing countries where ITS applications are still beginning to appear. The vast amount of data already collected through GPS (smart phones), weigh-in-motion (toll plazas) and other sensors needs to be standardized for efficient fusion of data from multitude of sensors. IIT (BHU) aims to be the center of excellence that would develop, facilitate and implement ITS in developing Indian cities into smart communities while at the same time preparing human resources equipped with interdisciplinary tools and techniques to understand, implement and evaluate ITS in modern India.

(e) Health and Family Welfare

A healthy and productive brain and mind system of an individual is a sine qua non for full economic development and contribution of the persona in the advancing society today. An efficient physiological and cognitive readiness of an individual has great contribution, not only to his health and welfare, but also to his education, employability and realization. The area of focus formulated here is Brain/Mind Healthcare, as W.H.O. study emphasizes that disease load due to Brain/Mind illness has the maximal economic burden to the society, even exceeding the combined burden of Cancer and Heart disease put together. Accordingly, IIT (BHU) has proposed the program om National Mission on DAPT on Brain/Mind Health (NM-DAPT-BMH). The two major aspects of healthcare are (i) Screening or Diagnosis, (ii) Therapy or Treatment, while other collateral aspects are modalities that enable the following attainments: (iii) Disease Prevention, (iv) Rehabilitation, and (v) Health Promotion. IIT (BHU) has well acknowledged expertise in the Health-related sector, having departments/schools/centres on Bio Medical engineering, Pharmaceutics, Biochemical engineering, as well as Centre on Tissue engineering & Biomaterials. Further, the IIT (BHU) has close collaboration with in-campus premier clinical institutions, such as Tata Memorial Centre – Varanasi (DAE, GOI), and IMS (BHU), the Institute of Medical Sciences, recently upgraded to AIIMS level institution, which has a nationally renowned Neuro Centre and departments on Psychiatry and Mental Health.

Diagnostic and Screening Systems: There is a crucial Indian need for formulation of non-invasive disease identification technology. Today, using principles of “Data Analytics”, the universally available high data throughput scanning, signalling or imaging systems furnishes a high-precision mapping of the structural and functional activity of organs or tissues. Naturally,

for the health technology industry, a greatly unfilled gap for the country is to develop digital diagnostic/screening systems validated for tropical neurological/mental health disorders, tested in Indian populace with local doctors in both public sector and private sector health/medical units. In numerous diagnostic cases, it is found that that A.I. and Pattern Recognition methods often outperforms the clinical diagnostic efficiency of an overworked busy doctor, whether in the U.S or in India.

Treatment Planning & Therapeutic Systems: Coming to the health management scenario, the advent of Medical Expert Systems and the International Collaborative Epidemiology Programs have demonstrated the very reliable validated ability of "Predictive Technologies". Thereby, one can enable: (i) the automated forecasting of the most efficient therapy protocol, and (ii) judicious selection and optimization of the most feasible therapeutic agents, whether drugs, physiotherapy, cognitive stimulation, electrical pace-making etc. Such platforms are formulated by devising informatics-based Therapeutic Decision-making Systems, along with Treatment Planning Systems, using Machine Learning and Pattern Recognition principles. Needless to say, these approaches use computational Operations Research techniques to maximize the clinical performance of the therapy, as well as minimize the side-effects, and keep the cost within insurance payment or affordability bounds.

DPR Apex Committee

The Indian Institute of Technology (Banaras Hindu University), Varanasi has constituted an Apex Committee to guide, mentor and suggest the development of Detailed Project Report (DPR) on National Mission on Interdisciplinary Data Analytics and Predictive Technologies (NM-DAPT) under national mission on DAPT. Composition of the Committee is

1	Prof. Pramod Kumar Jain Director, IIT(BHU)	Chairman
2	Prof. Satish K. Tripathi President, University of Buffalo, Buffalo N.Y., USA	Member
3	Dr. Sudhir Kumar Mishra DG, CEO & MD, Brahmos Aerospace, Ministry of Defence, GoI	Member
4	Prof. M.K. Tiwari, Director, NITIE, Mumbai	Member
5	Prof. Sunil Jha, Deptt. of Mechanical Engineering, IIT Delhi	Member
6.	Dr. Manoj K. Jain, Scientist G & Head, Knowledge Management and Systems, DMRL, Hyderabad	Member
7.	Prof. S. C. Srivastava, IIT Kanpur	Member
8.	Mr. Sunil Khanna, President & MD, VERTIV Energy Pvt. Ltd, Pune	Member
6	Prof. Shiho Kim, Director, Seamless Transportation Laboratory, Yonsei Institute of Conversion Technology, South Korea	Member
7	Dr. Lovneesh Chanana, VP-Digital Government (Asia Pacific & Japan), SAP Inc.	Member
8	Prof. B. N. Gangadgar, Director, National Institute of Mental Health and Neurosciences, Bengaluru	Member
9	Shri R. K. Pandey, Member (Project), NHAI, Chief Engineer, MoRTH, New Delhi	Member
10	Prof. Y. N. Singh, Dept of Electrical Engg., IIT Kanpur	Member
11	Prof. Rajiv Prakash, Dean, Research & Development, IIT (BHU)	Member Secretary (Ex-officio)

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Chapter–1

Mission Introduction

1.1 Context and Background

One important area that needs to be addressed for the rapid global rise of India is Interdisciplinary Data Analytics and Predictive Technologies based systems. This has the potential to resolve unprecedented challenges and stresses our country is facing, almost in each sector. NM-DAPT at IIT(BHU) is a huge opportunity to research, training and skilling in smart transportation, automated manufacturing to digital twins, smart power distribution to alternative energy creation to city scale water management, smarter ways of societal and industrial networks and information communication and Internet-of-Things for real time control of production lines, intelligent ways of urban and rural area and management e.g. waste management, water management tec., along with healthcare across the age spectrum, and much more. IIT(BHU) proposes to take-up this National Mission in the Data Analytics and Predictive Technologies to secure our future by creation of basic and advanced R&D infrastructure, manpower and skills, to achieve excellence at global fronts.

We, at IIT(BHU) have critically examined and have the firm view that Interdisciplinary Data Analytics and Predictive Technologies must be taken up as a National Mission. We opine that DAPT will serve to produce more jobs for our youth, globally. It will also provide a secure and strategic niche which the new industrial revolution has brought around the corner especially in terms of Industry 4.0, Society 5.0 and beyond. Our goal is to take lead during this starting phase itself, by generating new directions and training our youth in this field. DAPT is full of opportunities in diverse sectors of Indian Industry. The areas of focus could be in smart city verticals, national health missions, renewable and alternative energy, advanced products on intelligent sensors and systems, Ayushman Bharat, digital manufacturing, energy, defence and intelligent networks, health and well-being, and communication systems apart from multiple dimensions in which we can develop nationally scalable models for Swachh Bharat (Clean India) mission, pan India water resource mission and alike to start with. Specific action will be to start Centres of Excellence in these aforesaid areas (but not limited to): provide facilities to design and evaluate several technologies and algorithms, train youth at all levels, develop incubators and start-ups in niche areas of DAPT and deliver solutions to top level challenges, both nationally and internationally.

IIT(BHU) pledges to push commercialisation around promising MSMEs and to ensure diffusion of Industry 4.0 grade contributions in manufacturing and other sectors of services and Society 5.0 grade contributions in the lives of our esteemed countrymen. Where necessary, we

will collaborate nationally and internationally, for developing core yet indigenous technologies and products to compete in the upcoming global markets to avail emerging opportunities, with special attention towards the needs of the developing countries, especially India.

Embedding DAPT into cyber and physical systems will produce a new breed of intelligent systems, not only as an innovative ecosystem but it will drastically boost-up our economies and the way we live. To invest in research, training and skilling in smart transportation, automated manufacturing to digital twins, smart power distribution to alternative energy, smarter ways of societal and industrial networks and information communication and intelligent Internet-of-Things based products e.g. real-time control of production lines, creation of nationally scalable intelligent ways of urban and rural area management e.g. water and waste management, advanced healthcare across all ages, and much more. The Department of Science & Technology has launched a Mission on Cyber Physical Systems (NM-ICPS) to support establishment of specialized technology incubation hubs (TIHs), all across the country. The National Mission on DAPT (NM-DAPT) is well in-line with high aspirations and offers a strategy to achieve the stated vision.

The term DAPT is being introduced by IIT(BHU), for the first time, in its integrated form, although the roots of the term DAPT are older and deeper, as reported in various published literature, by way of calling it data science or artificial intelligence or predictive technologies and by many other terms which partially matches the mandates of DAPT. It is further explained that the term "interdisciplinary," as a prefix, stems from the fact that we generate data in each and every walk of life and activities. Once we capture sensor responses into the digital repositories, they become data and any such data can be analysed and correlated to give us a thorough understanding of the underlying system and an ability to predict the response in various situations. Therefore, DAPT is essentially neutral in the sense that data can emanate from any diverse discipline and analysing such data very well falls within its prerogatives. DAPT is the essential foundation of effectively utilizing data and systems underlying Internet-of-Things (IoT) and cyber and physical systems (CPS). Various milestones which represent the birth and growth cycle of DAPT are as in Table 1.1.

All these events have fundamentally influenced the need to impart intelligence to traditional ways of operating the current information society and digital economy. At present, many experts from various fields are paying close attention to the emergence of a new engineering

system which is: Interdisciplinary Data Analytics and Predictive Technologies based decision support systems (DAPT-DSS), opening an excellent opportunity to take major global lead.

Table 1.1 – DAPT and its predecessors

Year	Term	Landmark Cause
1850	Nation-wide Statistical Epidemiology	UK Cholera Epidemic across the country
1890	The First Big Data Problem	US National Census
1965	The First Data Centre	US Tax Returns and Finger Database
1989	World Wide Web	Berners Lee's proposal for Internet
1989	Knowledge Discovery in Database	Data Science picks up as Technology
2001	Big Data defined	Doug Laney's 3-D Dataflow
2004	Hadoop	The free and open source Big Data Engine
2006	GPU	General purpose computation

At IIT (BHU), the DAPT discipline will be applied to 5 domain areas of national importance, these domain areas are; 1) Telecommunications, 2) Power, 3) Road Transport and Highways, 4) Defence Research and Development, and 5) Health and Family Welfare. A brief description illuminating the context and background of each domain is as follows:

1) Telecommunications

In the Industry 4.0 paradigm, the cyber physical systems are connected with intelligent interfaces for real-time and off-line data analytics and predictions. DAPT is hence an over-the-top layer on physical systems carrying enormous amounts of sensors and actuators, feeding real-time system feedback to tiny on-board processors, performing on-the-edge, over-the-network or on-the-cloud data analytics and predictions and generating control signals being fed to actuators, usually distributed globally to control the system dynamics to deliver enhanced and crispier performance over many years of operation, generally, autonomously or with much less human intervention. Accordingly, DAPT imparts intelligent control over CPS for enhanced and sustained performance over the years.

To deploy DAPT, we essentially require CPS with a stable backbone compliant to the control requirements on the real physical system and must be deployed in the right manner. On the sensor side, the data being sent to the DAPT repositories must be intact, authentic and unadulterated. Therefore, at the very first stage of sensor deployment, the sensor node itself has to be capable of self-test and secured. The sensor nodes may be in millions spread across the globe, through internetworking and therefore, the delay which it involves in the information transfer can be significant and must be controlled. Therefore, highly accurate guaranteed-delivery network protocol stack will be developed along with necessary hardware. Retaining the essential characteristics of CPS, it needs be low energy and long transmission and should be supported with back-up energy source.

When the sensor nodes are connected wirelessly, then random fading of signals can also be a serious difficulty and for guaranteed-delivery, multi-path transmission is carried out with the expectation that at least one of the transmitted packet will be received at the gateway within the permissible delay criteria, usually much below a milli second, ideally within micro-seconds. Then comes the issue of multi-packet reception of the same information and hence, the gateway must be capable of keeping a track of the packet reception history. This means that the gateway as well as the senor node should also be able to process the information packet, almost in real time (within micro-second range) which will pose another challenge in the design of packet headers. Also, while we consider the wireless medium being used, there may be multiple co-existent networks viz. 3G, 4G, Industry 4.0, Adhoc, Mesh, LoRA and many others and to maintain conflict free competency across all platforms including the open source as well as the proprietary ones will be another significant challenge.

Once the data reaches the data repository, pattern recognition algorithms are used to generate variety of relevant and non-relevant inferences and then correlation and fixing of the most valuable or information relevance becomes another challenge. Normal AI-ML and other statistical methods are time consuming and bulky and to generate relevant actuation signal with-in the micro-second performance criteria will require massive parallelisation of software and hardware, to expedite the process within the actuation time-frame.

In a nut-shell, DAPT on CPS is a whole new paradigm, which is just the tip of the iceberg of the complications involved. It will require whole new set of sensing, actuation, computation and communication electronics, before we will be able to roll-out one such DAPT enabled CPS, to be known as Smart IoT or Intelligent CPS. A few indicative examples of DAPT

enabled CPS are smart city verticals, smart healthcare, intelligent transportation and pathway management, several applications in the area of defence, Smart City Solutions like smart parking, intelligent water, gas and waste management systems and much more.

IIT(BHU) as the pioneer in DAPT, will mount this most challenging mission across the globe and to put India as the leader in DAPT applications on CPS and IoT. We will develop and produce innovative inventions, especially keeping the system development time frame and cost to its lowest orders to meet the global challenges and hold the most of the market share.

2) Power

Smart, efficient, and reliable power/energy management plays a vital role in the infrastructural advancement of a country in the modern world. In the national mission on interdisciplinary cyber physical systems, DAPT is one of the domain areas and DAPT in power is one of the thrust/application areas useful in the technology development of environment friendly, efficient, reliable, and smart power/energy grid. Analysing the data at various node points (right from the distribution grid to the consumer/commercial loads) and making use of it with the help of internet of things (IoT) for better and user-friendly power management, is one of the most innovative developments taking place all across the world. Concept of smart, futuristic homes and cities having better user-friendly solutions, efficient and reliable power management are some examples in the modern infrastructural advancements of both developing and developed countries. The Ministry of Housing and Urban Affairs, Government of India has set Smart Cities Mission and 100 cities qualified for this in the Smart City Mission 1.0. Data analytics and predictive control of the smart power processors plays an important role in the realization of smart homes and cities. Further, harnessing power from the renewables has become one of the most prevalent solutions of the power problem of our country. Thus, integration of solar PV with smart homes/cities provides a meaningful solution to the country's dire need of power generation.

In view of this, the plan is to develop smart home automation technology with the system IoT activated smart devices that can be controlled remotely. These connected system devices will be smart because they are able to interpret and analyse the user data. In addition, the data collection also helps to improve the comfort and safety of consumers. The automation technology will be used to develop smart connected homes and further to develop smart cities. Further, with predictive technology patterns, the data will be analysed for forecasting the likely future behaviour of input and loads. Overall, the developed system add values to the smart

homes/cities and will have the properties 1) it will provide algorithm to locate models which provides usable insights, 2) it will help to reduce energy consumption, optimize power flow and reliability of the devices, 3) it integrates solar PV to reduce burden on the main grid, 4) it will give more intuitive system, 5) it will turn our home into a more practical digital data centre where the data related to the input and loads may be analysed for its optimum use, and 6) it will give a facility where data will be used to predict present and futuristic loads facilitating a test bed in the futuristic smart homes.

3) Defence Research and Development

Former Army Chief General Bipin Rawat has said in his key note address at the 11th edition of GEO Intelligence Asia "The armed forces are the repository of big data and there is a need to record and institutionalise the information and carry out predictive analytics using AI," (https://economictimes.indiatimes.com/news/defence). When looking at the defence environment for our country, it is very much necessary to not only look at all structured data but make full use of every type of unstructured data also. In a nation of a billion plus people, Big Data analytical tools deliver the crucial edge in staying on top of the Defence game. With a detailed strategy for the long term, India can bring its depth in IT to develop a solution for the challenges of the 21st century, one that is far more advanced than any other country in the neighbourhood as well as around the world. Defence organizations want to use the data that they have collected in the past to make more insightful, forward-looking decisions about readiness, logistics, manpower, intelligence, and a host of other critical defence concerns. A new generation of advanced analytics—high-level diagnostic and predictive— can provide them that opportunity. With these analytics, defence organizations can go beyond looking back at data to make projections. They can begin to drill deep into cause and effect, and determine the mathematical probability of future occurrences. [Analytics Handbook; © 2019 Booz Allen Hamilton Inc.]. There are innumerable problems which can be addressed through the DAPT. Identification of the application areas for mission mode execution can be made based on prioritized needs of the defence sector, and the interests of the various stakeholders and industry. The major need of the defence is envisaged requirement of Smart sensors. The Indian Military (air force, army and navy) is a user of a wide variety of sensor systems including electromagnetic, acoustic, mechanical, chemical, biological, and environmental. There is requirement of atomic-level sensor devices (quantum wires and dots), digital implementation, distributed system implementation (networking, data fusion, and societies of microsensor),

multidimensional signatures (multispectral, hyperspectral, and data fusion), and multifunctional sensor systems (common apertures for radar, communications, electronic warfare, and so on). The growth in these critical underlying technologies will determine the sensor capabilities available to future Military.

4) Road Transport and Highways

Transportation implies movement of items be it humans (to offer services) or goods (to be consumed). Transportation being the backbone of the economy, the more efficiently it is achieved, the more it would manifest in terms of resource saving, and creation of economic growth. The basic foundation of economy is movement of goods and services from one part of the world to another. Data is the new oil of the digital economy and it separates successful and struggling decision makers amidst a massive amount of movements that generates huge amounts of data gathered through moving (vehicles) as well as fixed (roadside sensors) systems. Integrating transportation activity and highway asset data from several sources is an essential component of a Smart India be it in urban roads or highways networks. To this end, the various components and aspects of Road Transport and Highways (RTH) would be taken up as a thrust/application area under DAPT. Broadly known as DAPT-RTH, this area would cover most essential aspects of transportation where data science and predictive technologies can harness the existing and future data towards automated and connected vehicle testing facilities, pavement monitoring analytics, vehicular emission modelling, travel demand forecasting, predicting economic impact of transportation improvements, driver behaviour research, crash avoidance system, real-time traffic monitoring, pedestrian navigation and indoor mobility mapping systems. These systems and methods have a potential to drastically improve the way goods and services are transported under normal conditions as well as under emergency.

5) Health and Family Welfare

It is well acknowledged that any investment in this health is an investment in a county's future. Particularly protection and enhancing Brain/Mind Health is a most pressing area, as the disability due to neural and mental disorders exceeds that of Heart disease and Cancer put together (WHO, 2005). Indeed, the disorders of the brain or the mind is not easily observable externally. In this Mission domain, DAPT methodology will be utilized to enable rapid affordable and universal healthcare, with automated processing across different connectivity channels. The full gamut of clinical care is incorporated: Screening, Diagnostics, Treatment,

Prevention, and Rehabilitation. Since the needs of Brain/Mind Health greatly vary differentially across the life-span, the Mission would address the full age spectrum: Infants, Children, Adults, and the Elderly.

A healthy and productive brain and mind system of an individual is a *sine qua non* for full economic development and contribution of the persona in advancing society today. An efficient physiological and cognitive readiness of an individual has great contribution, not only to his health and welfare, but also to his education, employability and realization.

The present proposal encompasses the protection and maintenance of a healthy brain and mind across all ages. This lifespan angle is important, as the society needs to enhance the life across both men and women along all the age groups: Infants, Children, Youths, Adults, Mid-age, Elderly. Regarding the full-scale practical application to the Health-care field, we consider that specific domain which has the largest disease burden, implying that any technological and computational methodologies formulated, will have the most substantial payoff for the society. Pertinently, the largest segment of the world's ill-health burden (32%, as per WHO-UN) deals with the disorders of Brain and its Cognitive/Psychological system, especially infirmities of the categories mentioned below.

The methodologies that are developed in this Mission can also be extended across ameliorating neuro clinical conditions or cognitive abnormalities, that involves neuronal damage, such as:

(i) Neurological and Neurosurgical disorders

Predictive Technology: A critical clinical problem is cerebral stroke. Often these forms a mild pre-stroke condition (Transient Ischaemic Attack, TIA, a very brief trance-like condition). In some patients, this resolves spontaneously, and in others it predisposed to formation of full-blown Cerebral Stroke. Predictive Analytics is critically needed to identify the sub-cluster of those TIA patients who are forecasted to have propensity of converting to stroke later. Important clinical data that need to be used are MRI diffusion imaging, Blood clotting biochemical markers, and some genetic signatures. Data Analytics: These patients need to be administered preventive medications against stroke formation. If cerebral stroke/ thrombosis clotting occurs, then one need Data Analytics, to decide the most suitable drugs/combinations, their dosages and durations (typically 3-4 drugs of different classes are combined, out of typically 25-30 drugs of the different classes available). The types of drugs are clot dissolvers, blood thinners, anti-inflammatory agents, preventive antibiotics, and clot preventers.

(ii) Mental health conditions

Predictive Technology: An important clinical issue is Acute Depression, which if not relieved, can lead to co-morbidities as psychosis, or to suicidal personality, which is the leading cause of death in prime-age adults in India (15-40 years age. Here Predictive Technology would be needed to map the behavior of depressive patients and then forecast the risk of suicidal tendency. Typical parameters that can be used as feature vectors are (i) brain biochemical changes from MRI spectroscopy, (ii) low voltage in evoked response in EEG-ERP, (iii) blood biochemical levels, etc. Data Analytics: If suicidal tendency is diagnosed, then Data Analytics would be needed to plan immediate intervention, and decide on dosage and duration of treatment, comprising of Tricyclic antidepressant drugs, Mood modulating drugs (as 5-Hydroxy Tryptamine reuptake inhibitors), anti-psychotic agents as Lithium-based pharmaceutics, and Electro-therapy. Thereafter, one needs also to properly select and optimize the frequency and period of cognitive-behavioural counselling therapy for maintenance duration.

(iii) Head injury in road accidents

Predictive Technology: Road Traffic Accidents causes India an economic loss of 7% GDP or $ 10.5 Billion every year. Nerve/Brain injury are there in 65% of these accidents. Most of the head injuries are closed, with brain concussion. A crucial issue here is to know whether there is brain's deep neural fibre tear (invisible from outside), this predisposed to permanent cognitive deficit and lifelong mental impairment. Here DAPT has vast applications. Predictive Technology can be utilized to whether the patient has predisposition to undergo permanent damage to brain and cognition. If this is positive, then interventional treatment is necessary. Data Analytics: A seminal aspect is to prevent the tear in brain fibres undergoing further degeneration. This can be undertaken by neuroprotective agents, as; (1) Physiotherapies as Transcranial Magnetic Stimulation therapy, (2) Pharmaceutic treatment, as by neuroprotection drugs of different classes, e.g. (i) neural axon myelinating agents, (ii) immune reaction neutralizing drugs, like microglial cell polarization reversal agents, (iii) anti-inflammatory monoclonal antibody agents. Data analytics can be used to administer patient-specific treatment, by selecting the proper combination ratio, dosage and duration of the different drugs, by matching against the genetic signature in blood assessed.

1.1.1 Data Analytics and Predictive Technologies

DAPT is the integration of pattern-recognition based approaches in traditional computation, communication, cognition, sensing and physical processes. DAPT based systems have embedded sensors and processors either placed as standalone or in networks, to monitor and control the physical processes by learning from past experiences through their operational models, creating feedback loops to better interact with the real physical world and vice versa. A multidimensional and complex system as DAPT is, the close integration of the information world and the physical world is realized through the combination of advanced algorithms and shallow and deep neural models for adding intelligence to traditional computing, communication and control technology. DAPT refers to the deep and seamless integration of traditional computational and physical resources to realize strategically engineered systems with adequate decision-making capability, usually in the form of shallow and deep networks to far exceed today's system performance in autonomy, functionality, efficiency, usability, safety, and reliability.

The development of smart infrastructures and services for a sustainable society requires extensive interdisciplinary research. The smartness comes by learning from the past experiences of running respective system(s) and by correlating between other similar components being observed and controlled. The entire system becomes better and better by learning from past experiences, form observations, inferences and controls. It also takes the advantage of the progress being made in the way newer networks, computing and controls etc., are re-modelled to leverage the possibilities achievable by integrating DAPT into cyber and physical systems.

The emerging discipline of DAPT holds the potential to develop smart infrastructures. DAPT can revolutionize the traditional physical systems by imparting intelligence through various neural and computational technologies and helps them refine their performance with experience. DAPT will revolutionise our traditional infrastructure such as electric power grids, health care, transportation, water, gas and waste management networks, and monitoring natural resources, in fact, it will revolutionise the way we live and interact with-in and outside the ambits of urban and rural social lifestyles. Novel concepts and theories developed in DAPT will provide profound insights into the nature of systems and the way a ‘system of systems’ grows into a massively networked world involving many intelligent subsystems coordinating with each other. Such a nationally and internationally scalable framework would enable us to

analyse the dynamics of the societal interactions and industrial production system in a unified yet unforeseen ways, across all the domains of human lives and nature.

Broad areas of interest under NM-DAPT at IIT(BHU) are the smart city verticals like smart transportation, smart power distribution and alternative energy systems, advanced heath care, smarter ways of societal and industrial information and communication networks and intelligent Internet-of-Things based products e.g. real-time control of production lines, automated manufacturing and digital twins apart from intelligent ways of urban and rural management e.g. nationally scalable smart waste management system, water management system etc. The world is quickly moving towards design and control of large-scale intelligent systems e.g. recommendation systems in e-commerce, where millions and millions of users are coordinated individually by using advanced DAPT. Theoretical frameworks for such large-scale, interconnected, systems have yet not matured. Tools such as optimization and control, stochastic analysis, queuing systems, and decision sciences still need to be better analysed and integrated to drive large-scale interconnected systems. Analysis of large and complex datasets consisting of information regarding hundreds of temporal and spatial variables also pose a challenge. Most of the systems constitute not only 'system-of-systems' but also a network of information networks. DAPT has tremendous potential to control and operate such interconnected systems with utmost consistency and reliability over years and years of continued operations.

DAPT is an interdisciplinary area of application to equip traditional systems with smart feedback control over widely distributed embedded computing systems by using the combination of large-scale system-level sensing and processing of the collected data either at local node level (edge computing) or at a distributed networked level (fog computing) and/ or at a data centre (cloud computing). DAPT transforms and integrates smart decision-making capability to traditional systems by embedding sensing, communicating, processing and actuation capabilities, usually scalable at internet levels i.e. globally. DAPT are newer paradigms to the traditional application of information technology to improve the performance of a system and is realized by having a closely coupled interaction between physical processes, networks and compute. The physical process is monitored and controlled by embedded (cyber) sub-systems via networked systems with smart decision support system on the edge/fog/cloud-based feedback loops to change their behaviour when needed. These subsystems work independently of each other with the ability to interact with the external environment. They go

beyond traditional systems employed in the industry about their complexity, requiring close networking with the appropriate disciplines which require specific tools for the analysis of the various properties of transportation and have the following characteristic.

- Systems of collaborating computational elements controlling physical entities
- Networks of interacting elements with physical inputs and output instead of as standalone devices
- Internet of Things, Data, and Services
- Interconnections between physical and virtual world models
- Ability for autonomous behaviour, such as self-control and/or self-optimization
- Internet-based business models, social networks, and communities
- Systems of systems
- New way of cooperating among distributed and intelligent smart networked devices as well as with humans

The diversity of DAPT applications ranges from the mini-scale to the large scale. Thus, DAPT is gaining growing importance in networking of embedded computing systems and components of Information and Communications Technology (ICT). DAPT is attracting much attention in recent years and is being considered as an emerging technology. It combines computation and communication capabilities with the physical world. It can add more intelligence to social life. It integrates physical devices, such as sensors and cameras, with cyber components to form an analytical system that responds intelligently to dynamic changes in the real-world scenarios. DAPT can have wide-ranging applications, such as smart city verticals viz. intelligent transportation, traffic control and pavement management, energy generation and power distribution networks, advanced healthcare, intelligent communication networks providing ubiquitous connectivity, assisted living, environmental control, and systems of systems like nationally scalable systems for city wide water, gas and waste management to name a few. DAPT also finds numerous applications in defence sectors like drone-based border surveillance, real-time monitoring and life support systems for the soldiers and much more.

DAPT in energy and power is the integration of power processing network with computation, communication, cognition, sensing, and embedded technologies. It is a multidimensional and complex system for smart power flow which refers to the deep and seamless integration of computational and physical resources for user friendly functionality, efficiency, usability, safety, and reliability. DAPT connects physical systems through various communication

technologies and helps them interact. Such infrastructure would include smart and intelligent electric power grids helpful for smart homes and cities. The new concepts and theories developed in DAPT are providing more profound insights into system interconnection of a big network involving many intelligent sub-systems coordinating with each other. Such an outline would enable to analyse the data and predict models for dynamics of the control, computation and communication in a unified way applicable specifically for smart intelligent power grids.

DAPT consists of intelligently coupled objects which cooperate and organize themselves and take autonomous or collective decisions. By using sensors, these embedded objects monitor and collect data from physical processes and networked systems and then make data globally available. Then, software applications can directly interact with events in the physical world, notably by merging them with the virtual links of Internet of Things (IoT), data for application of DAPT to deliver services.

Key areas of interest in DAPT in power systems are power electronic interface, embedded sensing, IoT, artificial intelligence, optimization techniques in a large distributed system with a due care for security of the data. Tools such as optimization and control, stochastic analysis, queuing systems, and decision sciences drive large-scale interconnected systems. Analysis of large and complex datasets consisting of information regarding variables help in forecasting of a load or input behaviour in the complex power grid. By and large in the DAPT, the physical process is monitored and controlled by embedded (cyber) sub-systems via networked systems with feedback loops to change/adapt their behaviour as per the requirement. These subsystems data work independently of each other with the ability to interact with each other as well with the external environment. Overall, DAPT reflects a vision of a technology that uses the big data and soft prediction of models for operating, connecting, and forecasting the physical behaviour of any intelligent/smart electric power gird.

DAPT universally revolutionises the traditional platforms encompassed with popular technologies - Internet of Things (IoT), Industry 4.0, the Industrial Internet, Machine-to-Machine (M2M), the Internet of Everything, Sensors (trillion sensors), and the fog (like the cloud, but closer to the ground). However, in particular, IoT like a platform on which DAPT applications are embedded, much the same way as the World Wide Web is an application running on the Internet. All of these reflect a vision of a technology that deeply connects the physical world with information world. In broader views, the term DAPT is the foundation on which all smart and intelligent systems will be based on. DAPT will make systems more robust,

reliable and resilient. DAPT has been identified as a key research area under the NM-ICPS and has been listed as the high priority area for research, industry, healthcare, defence, and the society.

1.1.2 Major Technology Domains identified for DAPT Implementation in the selected application areas

Some of the major technology domains identified for the DAPT implementation is given in the Following table. These technology domains cover all the five identified thrust/application areas.

S. No.	Technology Domains	Description
1	**Power Electronics**	Power Electronics is not only an indissoluble technology for DAPT in Power but also for any modern system. It processes the raw available input according to the load demand. The advent and evolution of Power Electronics has made the concept of smart, intelligent power distribution a virtual reality. In DAPT, the power electronics interface reviews the input/output data and accordingly process and the control the power flow for realizing a smart, intelligent power grid. High power density power processors have reduced the weight and volume of the overall system.
2	**Smart Sensors and Systems**	Mechatronics is now being revolutionised by the integration of large number of sensors, sensor networks, embedded processors and actuators, integrating mutually and interconnect mechanical engineering, electrical engineering/electronics and computer science (also often called information technology) such that the interactions constitute the basis for the application of DAPT based intelligent breed of high-performance products. Electro-mechanical engineering products are now getting transformed by the application of DAPT. DAPT is connected, embedded systems which directly record

		physical data using sensors and affect physical processes using actuators, both locally or on the cloud. DAPT enabled systems evaluate and save recorded data, use globally available services and interact with operators via multimodal human-machine-interfaces.
3	**DAPT enabled Embedded systems**	In traditional embedded systems, the emphasis tends to be more on the computational elements, and less on an intense link between the computational and physical elements. In DAPT, embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. DAPT is creating the next generation of intelligent ICT embedded systems that are becoming pervasive in every aspect of daily life. In DAPT, embedded computation and communication devices, together with sensors and actuators of the physical substratum, are federated in heterogeneous, open system-of-systems.
4	**Smart Internet of Things (SIoT)**	DAPT adds smartness to the Internet of Things (IoT) keeping the basic physical architecture same and by integrating computation on the edge or cloud, adds the system analyse its performance and predicts its behaviour for optimal performance delivery. Nevertheless, DAPT incorporates a higher degree of seamless coordination between physical and cyber space. The concept of embedding intelligence to. the objects on the network transforms the "Internet of Things" to Smart Internet of Things (SIoT).
5	**Narrow Band IoT Architecture**	Cellular networks are not optimized for applications that only transmit small amounts of infrequent data. Sensor nodes also require power saving capabilities, making existing mobile communication standards unsuitable for

		inexpensive devices that require battery lives of several years. NB-IoT will connect many more devices to the Internet of Things and make many new applications a reality. It is optimized for applications that need to communicate small amounts of data over long periods of time. Since it operates in licensed spectrum, it is secure and reliable providing guaranteed quality of service.
6	**Crowd Sensing based Framework**	Measurement and collection of data through different kinds of sensing devices (e.g., smartphones) by a large mass of users, with the goal of sharing collected data with Smart City citizens through a common ICT platform for the sake of the community wellbeing is crowd sensing. In this technique humans equipped with sensors (usually smart-phones) generate data (i.e., pictures or videos) during their visit in certain area of interest. DAPT can hugely take advantage from such data and predict better and more accurate inferences.
7	**Software-Defined Networking (SDN) and Fog Computing (FC)**	SDN, a new networking paradigm, reduces the deployment, interoperability and management complexities in high performance networks of industry 4.0. It also provides a global view of the underlying network making it highly secure. On the other hand, fog computing, pushes the data to the network edge and reduces the cost (in terms of bandwidth consumption and high latency) of "big data" transportation through the core network. DAPT will seek these platforms for large scale data collection and on-the-fly analytics.
8	**Heterogeneous and disaggregated**	These approaches expand the boundary of server computing by breaking tight coupling between a server resource (compute, memory, storage and NIC) to multiple server. Based on Application requirement we

	computing at the edge	synthesize the logical compute machine from resource pool. For based performance its good to have this resource disaggregation with in a chassis and then this chassis becomes unit of mobile edge computing (MEC) service delivery. In the R&D perspective, we can go with separate Compute Blade connected through 10G Ethernet. As we have moved into Industry 4.0 era, CPU cannot continue to work as central orchestrator for all compute function. We need to have a platform where different compute resources can be assembled to create a logical computer for heterogeneous computing requirements as shown below. This also involves a programming framework where different computing resource can be engaged.
9	**vRAN (Virtual Radio Access Networks) for Hardware Abstraction**	Virtualization entails the migration from custom-built network nodes to network functionality implemented in software running on a generic hardware compute platform. In the RAN domain, vendor agnostic commercial off-the-shelf (COTS) hardware has the potential to enable innovation across a range of software ecosystems. A separation of the upper and lower parts of the RAN was standardized in 3GPP R15, where a higher-layer split was specified with a well-defined interface (F1) between two logical units: The Centralized Unit (CU) and the Distributed Unit (DU). The CU—with less stringent processing requirements—has been more amenable to virtualization than the DU and its functions that are closer to the radio. For full-stack RAN virtualization, the DU is connected to the radio via a packet interface known as enhanced Common Public Radio Interface (eCPRI).

10	**AI-ML enabled in Computing**	DAPT imbibes algorithms and approaches used in artificial intelligence using visual perception, speech recognition, decision making, and language translation. By exploiting machine learning computers can self-learn from data using advanced algorithms, understand patterns in large data sets, make predictions as they encounter new data using pattern recognition, and adapt independently. DAPT are about figuring out what is happening, why it is happening, and uses statistical models and algorithms to derive insights to support decision making.
11	**Digital Reality (Augmented, Virtual and Mixed)**	Augmented reality (AR) acts as a virtual layer on top of the world in front of you, and is in a new age of discovery and innovation. While early AR applications depended on a smartphone or tablet, they will soon expand into wearable devices like smart glasses requiring a different kind of UX and design process—thinking outside the confines of a smaller screen.
12	**Time Sensitive Networks**	TSN is the IEEE 802.1Q defined standard technology to provide deterministic messaging on standard Ethernet. TSN technology is centrally managed and delivers guarantees of delivery and minimized jitter using time scheduling for those real-time applications that require determinism. TSN is a Layer 2 technology. The IEEE 802.1Q standards work at OSI Layer 2. TSN is an Ethernet standard, not an Internet Protocol standard. The forwarding decisions made by the TSN bridges use the Ethernet header contents, not the IP address. The payloads of the Ethernet frames can be anything and are not limited to Internet Protocol. This means that TSN can be used in any environment and can carry the payload of any industrial application.

13	**Big Data**	DAPT thrives on the data from M2M and IoT, communications, and integrates heterogeneous data from multiple sources with security and privacy, into the cloud based data platforms. Big data analytics is a rapidly expanding research area spanning the fields of computer science, information management. It has become a ubiquitous term in understanding and solving complex problems in different disciplinary fields. These include engineering, applied mathematics, medicine, computational biology, healthcare, social networks, finance, business, government, education, transportation and telecommunications. To effectively synthesize DAPT, big data generation from devices using IoT and machine learning techniques will be employed. DAPT extracts information from big data using various techniques such as regression analysis, clustering, Bayesian methods, decision trees and random forests, support vector machines, reinforcement learning, ensemble learning and deep learning deployed in distributed computing and storage paradigm.
14	**Artificial Intelligence**	Use of Artificial Intelligence (AI) in the context of DAPT enabled cyber-physical systems will be an intrinsically integrated relationship between data, hardware, software and human participants. DAPT provides a comprehensive solution to the industry to leverage from traditional technologies such as AI, machine learning, reasoning, natural language processing, speech and vision, and human-computer interaction; it will help improve human decision-making and given advances in speech recognition, computer vision and sensor cognition, it would allow for deeper and broader penetration of intelligent systems in our lives. Rapid

		development in DAPT will support faster and more realistic products like level 6 autonomous cars and systems as promising products.
15	**Wireless Sensor Networks (WSN) & Intelligent Sensing**	The DAPT can peep into the past data and find prospective outcomes for the events of interest. The emerging DAPT must be robust and responsive for its implementation in coordinated, distributed, and connected ways. It is expected that future DAPT will far exceed today's systems on a variety of characteristics, for example, capability, adaptability, resiliency, safety, security, and usability. With the rapid development of computing and sensing technologies, such as ubiquitous wireless sensor networks, the amount of data from dissimilar sensors and social media will increase significantly. Conventional data fusion algorithms such as registration, association, and fusion are not effective for massive datasets and DAPT will only be able to deliver such responses.
16	**Neurocomputing**	Nerve circuitry and Biological Neuron Processing have inspired the development of very simplified models as Artificial Neural Network, and also laying a foundation of parallel processing. This furnishes the basis of current advances in Convolutional Neural Network, Stratified Intelligence, and Deep Learning. These methodologies are becoming the fundamental platforms of DAPT methodologies. Particularly, these are used for pattern recognition and approximate reasoning approaches, particularly when applied to inexact and fluctuating systems, as human, social, and natural systems. Other applications pertain to real-life systems, particularly where biological or environmental perturbations are

		involved, as in meteorology, weather forecasting, ecosystem analysis, agriculture, and geological analysis.
17	**Brain Imaging**	Neuroimaging technology, using MRI scanners, Functional MRI (fMRI) imaging, and Connectome Mapping of the human brain, has revolutionized Data Analytics and Predictive Technology, particularly after the starting of the UN-facilitated International Brain Initiative, the European Union's E.U. Human Brain Project, Japanese Brain Program (Brain/Minds project), and the Federal Government's U.S. BRAIN Initiative (Brain Research through Advancing Innovative Neuro-technologies). Indeed, the perceiving brain of the observer can now be modelled computationally to the level of 1 single neuron. Using MRI scanners, one can find out in detail the individual nerve fibres and separate neuro cell circuitry of the human brain, that sees an object, perceives it, and can then later visualize and imagine the object, even when the object is not there physically. This has given birth to the new discipline of Neuromorphic Computing, of how to develop. Neuroimaging has contributed greatly to the DAPT aspects of Brain/Mind health, as the modalities can readily screen disorders and predict future risks, and help develop the most optimal treatment modalities.
18	**Genomics**	The successful completion of the International Human Genome program, has been the text-book case of success of DAPT methodology for betterment of each citizen in the world, the program being the largest international research program, involving many countries including India. All the alphabets and words in man's biological book is now known, and these DAPT techniques now massively help to prevent diseases, select specific drug

		for a particular diseases and track susceptibility of infections. New treatment modalities have evolved, namely the personalized treatment, and development of new medicinal agents, namely antibodies, biologics, and living cells (immunotherapies). The new I.T. industry sectors, as Bioinformatics and Pharmacoinformatic, have taken shape, employing vast populace worldwide.
19	**Optimizations**	The field of optimization has been the backbone or traffic engineering be it shortest route selection, network delay minimization, public transportation scheduling, signal timing optimization, airline ticket price optimization, flight trajectory optimization, minimum fuel consumption routing, supply chain and logistics optimization, travel cost minimization, freight transport minimization, and many others. Algorithms and mathematical techniques pertaining to optimizations can be boost transportation modelling and decision making through high computing environment that are built for big data analytics and prediction.
20	**Computer Vision**	Image processing and computer vision technologies has a wide range of applications in transportation data analytics and predictive technologies for their non-expensive and easy deployment. For example, automated license plate recognition, vehicle classification, detection of moving vehicles, vehicle tracking in a small area, traffic flow analysis and management, intersection monitoring for red light running and wrong way driving, vehicle trajectory extraction, video based parking management, pedestrian detection, lane detection, traffic sign detection, road condition monitoring, collision avoidance systems, and driver monitoring.

21	**Geographic Information System (GIS)**	GIS significantly aids in planning, monitoring and managing complex systems involved in transportation planning and management more effectively. It helps in determining capacity enhancements, improving operations, and identifying the strategic investments for optimally running the transportation system. Major application domains include highway management, traffic modelling, crash analysis, crash hot spot analysis, effective incident management, and route planning. With visualization of real-time data, transport planners can more easily identify problem locations and thus help improve the overall travel experience more efficiently and economically. Spatial analytics can enhance patterns discover to better understand travel behaviours and to determine areas where measures can be taken to reduce the number of incidents. Further, GIS maps can help convey information to decision-makers (policy effectiveness) and the public (new route, or change to route etc.) more effectively
22	**Technologies required for DAPT enabled Defence Applications**	Today predictive interdisciplinary analytics is playing an important role in the defence (DAPT), specifically those pertaining to combat readiness like defence equipment and their parts replacement, effectiveness of a soldier in a real combat scenario and medical attention requirement in a particular combat scenario etc. Apart from these some crucial areas of defence like (a) border surveillance and role of drones and radars for surveillance, (b) microwave techniques for imaging, (c) stealth technique based on advanced polymer composites, (d) 5G for defence communications, (f) power systems for defence, (g) explosive detection, (h) smart sensors for soldiers and

		(i) and biosensors to know the readiness of soldiers (j) Advanced lightweight composites etc.

1.1.3 Advantages of DAPT

The advantage of DAPT is a promising solution for the integration of the physical and cyber world due to several benefits such as the following.

(i) Network Integration

DAPT has the interoperability with WSNs and Cloud Computing. It may provide compliance with networking standards. DAPT involves multiple computational platforms interacting over communication networks. DAPT provides network integration characteristics such as media access control techniques and their effects on system dynamics, middleware, and software that provide coordination over networks control over the timing of network transactions and fault tolerances.

(ii) Interaction between Human and System

Modelling and measuring situational awareness-human perception of the system and its environmental changes in parameters are critical for decision making. This is an absolute necessity for complex and dynamic systems. Some DAPTs include human as an integral part of the system which makes the interaction easier because usually, humans are difficult to model using standalone systems.

(iii) Mapping Human Structure & Function

DAPT is uniquely suited to map time-varying dynamic causative pathway mapping in biological or cognitive systems, and thus can find causative pathways that cause diseases, delineate risk factors, and also optimize the protocols of clinical diagnostics or treatment. A humongous number of Genes, Cells, Neurons, Circuits, and Synapses are involved in the body, and only high-performance computational advances of DAPT are found to successfully deal with the problem.

(iv) Cognitive Processing & Psychometric Mapping

There has been very effective formulation of Parallel Distributed Processing, Soft Computing, and Fuzzy Logic as the grammar of human cognition and thinking. Thereafter, ML and AI has very effectively used in understanding the different stages and dynamics of conscious, subconscious, and unconscious mental operations, incorporating cognitive processing at different perceptual intensities, and in terms of multimodal intelligences (symbolic intelligence, fluid intelligence, syncretic

intelligence). Typically, these processes are measured by large amount of psychometric data, and then autoregressive temporal analysis are performed. The scope of DAPT lies in all the aforesaid steps.

(v) Dealing with Certainty

Certainty is the process of providing proof that design is valid and trustworthy. Evidence can include formal proofs or exhaustive tests in simulations and prototypes. DAPT is designed to be able to evolve and operate with the new and unreliable environment. DAPT can demonstrate unknown system behaviour to study further and evolve into a better system.

(vi) Better System Performance

With the close interaction of sensors and cyberinfrastructure, DAPT can provide better system performance in terms of feedback and automatic redesign. Better computational resources and cyber subsystems in DAPT ensure the presence of multiple sensing entities, multiple communication mechanisms, high-level programming language, and end-user maintenance which further ensures the better system performance by DAPT.

(vii) Scalability

DAPT can scale the system according to demand utilizing the properties of Cloud Computing. Users can acquire necessary infrastructure without investing additional resources. DAPT is inherently heterogeneous as it combines physical dynamics with computational processes. The physical domain may combine mechanical motion control, chemical processes, biological processes, and human involvement. The cyber domain may combine networking infrastructure, programming tools, and software modelling. DAPT can provide design methodologies and tools that support those methodologies, which scale to large designs and promote understanding of complex systems.

(viii) Autonomy

DAPT can provide autonomy due to having sensor-cloud integration. Typically, DAPT is a closed loop system, where sensors make measurements of physical dynamics. These measurements are processed in the cyber subsystems, which then drive actuators and applications that affect the physical processes. The control strategies in the cyber subsystems are adaptive and usually predictive.

(ix) Flexibility

Present systems based on DAPT provide much more flexibility compared to the earlier systems.

(x) Optimization

Present sensors and cloud infrastructure offer large optimizations for a variety of applications. This capability opens the pathway for DAPT to optimize the system in wide extent.

(xi) Faster Response Time

DAPT can provide faster response time due to faster processing and communication capability of sensors and cloud infrastructure. Fast response time can facilitate the early detection of a remote failure, proper utilization of shared resources such as bandwidth etc.

1.2 General Description of the proposed Mission

1.2.1 NM-DAPT Scope

The DAPT and associated streams and on all aspects of DAPT research in India will be coordinated under the umbrella of NM-DAPT with a broader scope of Translational Research, Technology Development, HRD, Start-up development. The Mission would institute research through academic collaborations and foster in-depth investigations to understand the processes and phenomena that are in operation leading to the development of DAPT applications. A dedicated group of scientists, in collaboration with several other national academic and research institutions of excellence, associated with industry, would carry out major research programmes under directed research and extramural funding mechanisms to meet the requirements of Ministries/Departments/ Industry. It will establish links with specialized institutions in the country and abroad for establishment and strengthening of advanced facilities for research. The DAPT would also establish workable research collaborations with International academic institutions for the advancement of DAPT and associated research in the country.

IT systems will be built around networked sensing systems on real physical machines and systems, storage and computer systems and supplies that adhere to a defined standard and be linked up as DAPT. Using these technologies will make it possible to add smartness to machines along the value chain flexibly. This will enable highly efficient manufacturing in which production processes could be monitored, predicted and controlled, dynamically at short notice with minimized downtime. The level of efficiency, quality and customisation that will be possible through the amalgamation of DAPT with automation, Data Science, AI and IoT based systems will revolutionize the economy as a whole.

However, DAPT being a cloud enabled augmentation technology, there will be much less issues related to jobs and the job market will only expand during all the times, although the required skills set will change. In case of India, application of DAPT will instantly give a significant rise in quality of performance with more production with lesser input. The paradigm shifts that DAPT is bringing needs to be understood holistically. It is a global phenomenon and a paradigm shift; in a paradigm shift everyone comes down to ground zero. Those with required technical skills will be able to resurrect and reposition themselves to meet the new challenges. The same is true for countries and economies.

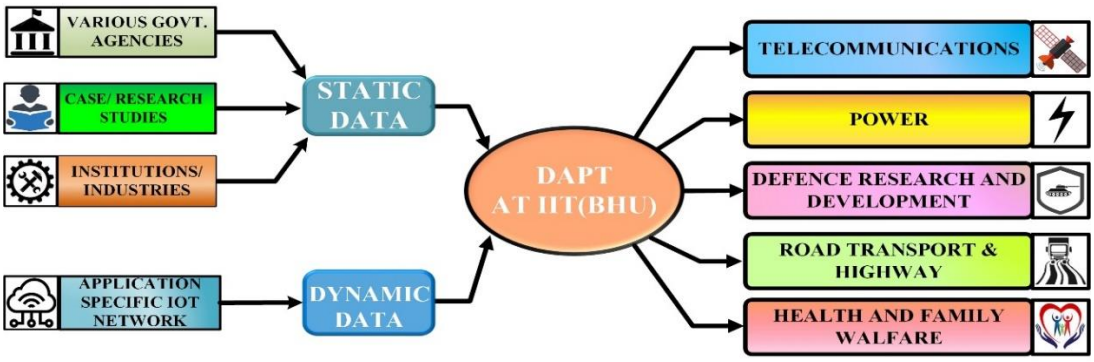


Fig.1.1 Representative block diagram of NM-DAPT at IIT (BHU).

In the global IT industry, India has a significant advantage in the IT enablement part of the value chain. As per NASSCOM estimates, while Indian IT exports are likely to grow in the range of 9 percent annually, the domestic market is expected to rise by a modest 9-12 percent. Indian IT companies are now well recognized for delivering quality, have proved their capabilities of timely execution of projects and are best positioned to ride global recovery. This gives India a unique advantage of positioning itself at the forefront of emerging technologies like DAPT. However, a holistic approach encompassing R&D, technology development, human resource development, innovation and start-up ecosystem development and interdisciplinary collaborations shall have to be addressed timely and the proposed DAPT Mission aims towards that.

NM-DAPT scope at IIT (BHU) is shown by the representative block diagram in Fig 1. As shown in Fig. 1.1, the NM-DAPT at IIT (BHU) has five application areas, 1) telecommunications, 2) power, 3) defence research and development, 4) road transport and highways, and 5) health and family welfare. The input to the DAPT may be static or dynamic data. The static data will come from various Govt. agencies, case/research studies or

institutions/industries and the dynamic data will be taken from the application specific IoT network.

1.2.2 Mission Aims and Objectives

(a) Aims

Cities are the engine of economic growth of every country. As per the smart city mission statement and guidelines 2015 by Ministry of Urban Development, Government of India, 31% of the population lives in urban areas and contribute to the 63% India's GDP. By 2030, 40% of the country's population are expected to live in urban areas and will contribute to the 75% of the India's GDP. This requires a comprehensive development of the physical infrastructure and IIT (BHU) has planned application of DAPT on the five areas, i.e., 1) Telecommunications, 2) Power, 3) Defence Research and Development, 4) Road Transport and Highways, and 5) Health and Family Welfare. At IIT (BHU), the DAPT will be implemented on these identified thrust/application areas for holistic development on the following specified points.

(1) Develop Industry 4.0 compliant software and hardware protocol stack to suit to the critical requirements of DAPT enabled physical system for stable real-physical system control.

(2) Develop nationally scalable critical technology solutions for the society and industry viz. City Verticals: Smart Energy & Power, Intelligent Transportation & surveillance, Ubiquitous Healthcare Systems and Intelligent Networks and Communication Systems and DAPT applications on Defence Systems apart from solving societal problems of water, gas and waste management and beyond, for societal and commercial use, nurture start-ups and increase in the job market.

(3) Produce skilled manpower for advanced technology development and deployment of DAPT enabled Intelligent CPS and Smart IoTs.

(4) Development of DAPT based environment and user-friendly smart grid infrastructure for optimal power/energy flow.

(5) Establish India as a pioneer in designing, manufacturing and implementing low cost ITS technologies to manage traffic safely and efficiently while appropriately informing the road users in an apt and timely manner.

(6) Establish facilities to support development of sustainable transportation and traffic management systems.

(7) Produce world class transportation modellers and traffic management experts.

(8) Establish a first of its kind Highway Knowledge Centre for capturing various transportation activities and behaviours to predict future scenarios and estimate their impact on the environment and economy.

(9) IIT (BHU) is already one of the knowledge partners in the UP-Govt. defence corridor scheme and thus, the aim is to make India a leading player in DAPT defence technologies.

(10) Achieve translation of DAPT technologies for societal and commercial use, nurture start-ups and increase in the job market.

(11) Produce next generation technocrats in DAPT technologies.

(12) Enable India to be a leading resource country in Affordable Brain/Mind Health delivery utilizing cyber-physical technology and digital processing.

(13) Catalyse the cross-fertilization of Neuroimaging, Neuroinformatic and Bio-engineering for developing improved health care platforms and medical device ecosystems.

(14) Produce the next generation of medical professionals and technologists well versed in leveraging analytics and predictive techniques for mental health betterment of the society.

(b) Objectives:

The objectives are defined as per the identified thrust/application/application areas and are explained as detailed below.

1) Telecommunications

Industry 4.0 is driving the trends for digital transformation. Digital transformation is the change associated with the application of digital technology in all aspects of human society. The transformation stage means that digital usages inherently enable new types of innovation and creativity in a domain, rather than simply enhance and support traditional methods. Key trends for digital transformation under Industry 4.0 include IoT, AI, Edge computing, Block-chain, and communication with guaranteed delivery service with less than a milli second time constraints for many applications.

Following this trend – since everything can be digitized, transformed, transported and stored, we expect that the telecommunication infrastructurewill also be transformed into digital infra at all levels. After considering many applications like Industry 4.0, Video Analytics, AI enabled applications, virtual Radio Access Networks, AR/VR, Security etc.

we understand that there will be four enablers for this massive transformation as mentioned below:

1. Industry 4.0 – 5G hyper connection and innovative Air Interface
2. Massive scale Transport- Ethernet/IP, Time Sensitive Networking (TSN - IEEE 802.1)
3. Low Latency computing at network scale e.g. Multi-access Edge Computing (MEC)
4. Massive "Softwarization" and "Virtualization" e.g. SDN and NFV etc.
5. This thrust/application area will focus to connect these four dots to create a massive innovation engine around Mass Scale Industry 4.0 transport, Low Latency Hyperconverged Computing & Massive softwarization for automation and control.

2) Power

The aim of the DAPT in energy power is to develop a technological centre for solar PV integrated smart hybrid grid having optimal power/energy management to facilitate smart homes/cities concept in the Indian context. The developed smart grid will have customized dc and ac bars. The dc and ac loads can be connected directly to these bus bars through smart switches. The proposed system will have IoT activated smart devices which are able to analyse and interpret user data and help to improve the user comfort with better/optimized power flow networking. These smart devices may be controlled through a local or offsite server. Fig. 1.2 shows the system representation of the proposed IoT activated smart homes.

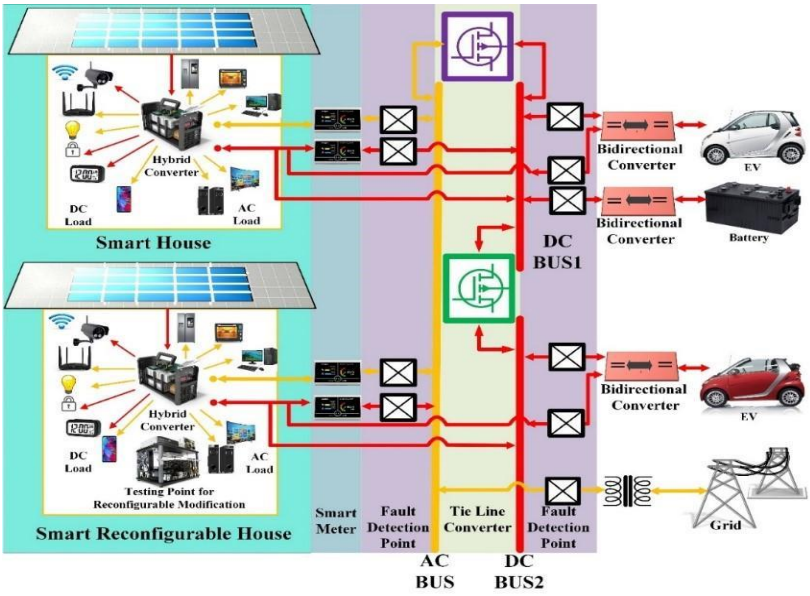


Fig. 1.2 System representation of the IoT based smart homes.

As shown in Fig. 1.2, there are two model smart homes with ac and dc lines simultaneously. The main innovative features of the developed smart homes are following.

1) With the help of smart inverters, simultaneous dc and ac outputs would be produced from generated power of solar PV. The dc and ac loads may be connected directly to these dedicated busses (thereby avoiding additional use of local adaptors) through smart IoT activated switches. The power may be taken from the grid though ac bus and with the help of tie line converter, ac power may be exchanged with the dc bus. In addition, homes will also be connected through the tie line converters. Thus, there will be provision of flow of power from home to grid, grid to home, one home to another home, one load to the other load as shown in Fig. 1.3.

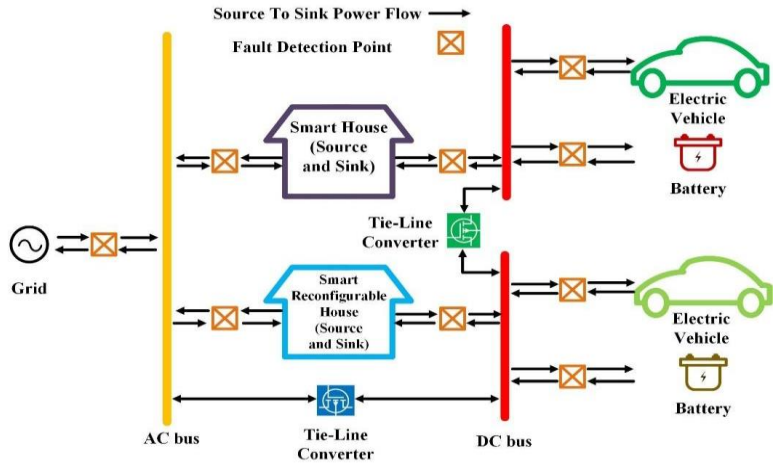


Fig. 1.3 Representation of multidirectional power flow of the system.

This gives a complete power loop where according to the need one may supply another and in this way optimize the use of power, increase the system efficiency, and reduce burden on the utility grid. Further, all the powers transfer would be done remotely through smart devices.

2) There will be a unique kind of smart home (one or more may be identified for this purpose) where load data will be analysed to predict the current and futuristic loads. This technology will help a test bed in the smart home. Such a type of home is represented as a reconfigurable smart home in Figs. 1.2 and 1.3.

3) The data from the distribution grid and the load point would be analysed and an optimal model would be predicted for the load requirement in each smart home. A look up table will be prepared and based on that a dynamic load would be sanctioned

with a upper ceiling (instead of a constant blanket load sanction) according to the need in different hours of a day. This will ensure the optimum usage and distribution of the generated power.

4) The various node point data will be analysed and prediction of the impending fault and giving alert for the already existing fault.

Fig. 1.4 describes the IoT operation for remote control of the power flow in the proposed smart homes. It may be observed that the loads may be controlled through smart switches and smart inverters with a local central controller installed in the home itself. Moreover, the central controller is also connected with the sim-based routers and thus, the devices and processors can be controlled remotely through mobile phones, tabs etc.

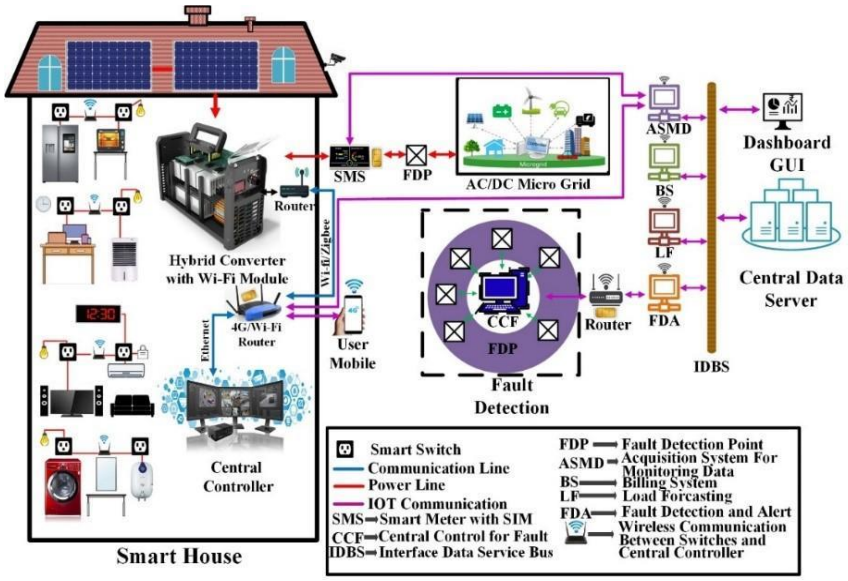


Fig. 1.4 Description of the IoT for power flow management.

Data will be collected at various node points as shown in Fig. 1.2 and the same will be analysed to prepare a predictive model for impending fault and giving alert. Through the smart devices in operation these alerts will be received on the phones, laptops, tabs etc. As shown in Fig. 1.2, the IoT activated smart metering system will calculate the dynamic consumption and all the information such as tariff charges, units consumed etc. will be available to the user on his/her mobile phones or other electronic gadgets. The concept of IoT activated smart homes discussed in Figs. 1.2, 1.3 and 1.4 will be extended for realization of the smart cities to contribute to the Smart Cities Mission of the country.

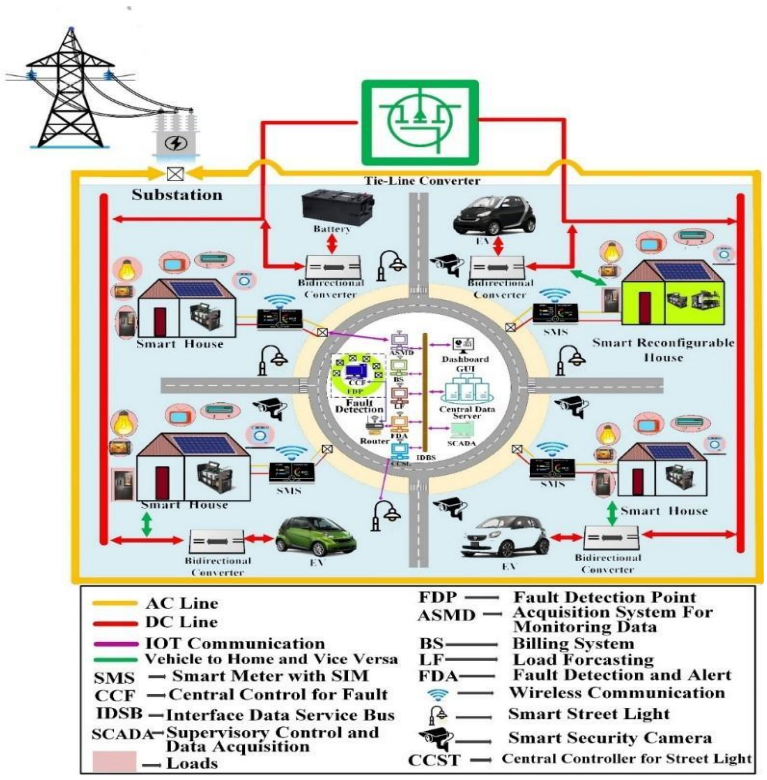


Fig. 1.5 Representation of IoT operated smart city.

Fig. 1.5 shows the representation of smart cities by extending the concept of smart homes discussed in Fig. 1.5. The further extension of the concept at the community level is shown in Fig. 1.6.

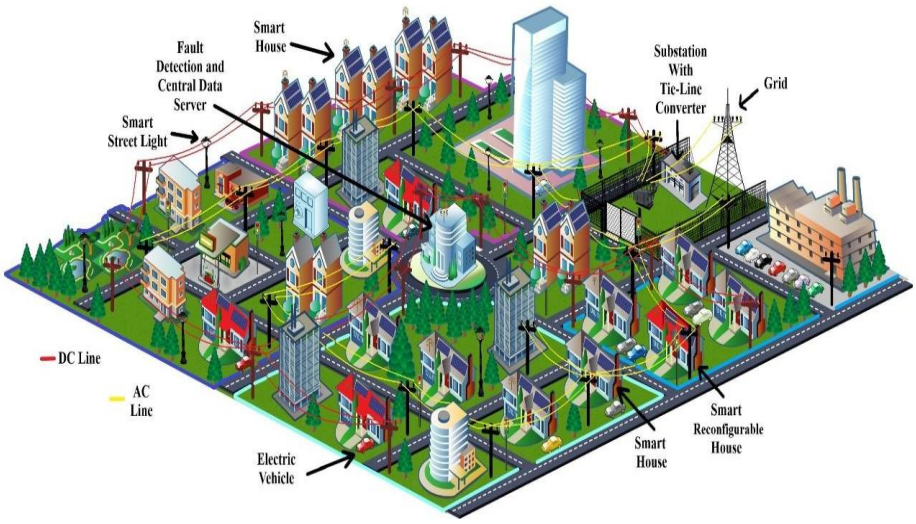


Fig. 1.6 Smart cities representation at community level.

Fig. 1.7 shows the description of the IoT for smart/optimized power flow management for a smart city. It is also important to note that the data at

distribution node, solar PV, and load point would be analysed and processed to take care of smart grid cyber security, prevention, and detection to counter any existing and potential threats as per the National Institute of Standards and Technology (NIST) guidelines (NISTIR 7628 report).

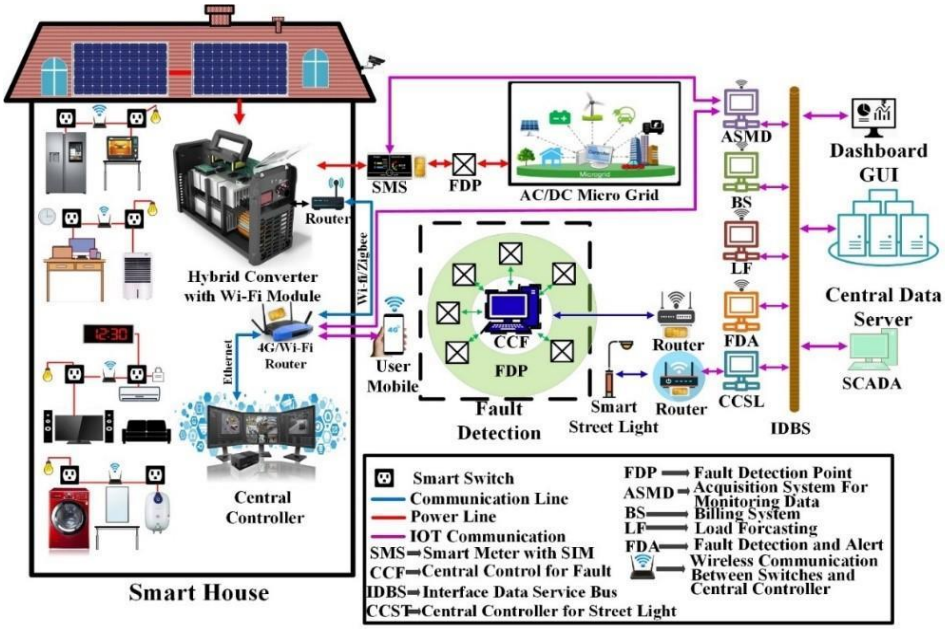


Fig. 1.7 Description of the IoT for power flow management for smart city.

Overall, the entire plan will have the following three levels.

1. Level 1: Development of IoT activated smart homes and smart reconfigurable homes with capability of power transfer form grid to home, home to home, home to grid, load to load, load to grid.

2. Level 2: Extending the concept used in Level 1 to realize IoT operated smart city.

3. Level 3: Impact and optimization of various datasets for dynamic load forecasting for optimized dynamic load sanction as per the generated input.

3) Defence Research and Development

Today predictive interdisciplinary analytics is playing an important role in the defence, specifically those pertaining to combat readiness like defence equipment and their parts replacement, effectiveness of a soldier in a real combat scenario and medical attention requirement in a particular combat scenario etc. We are expecting evolution in imaging systems and smart sensors in the coming decade in view of change in the nature of War.

In the near future, defence needs modern imaging systems and smart sensor systems enabled greatly by new technologies. The role of these technologies will be more focused in the following areas:

i. Border surveillance and role of drones and radars for surveillance

A representative model of border surveillance system is shown in Fig. 1.8. It may be observed from Fig. 1.8 that geospatial data plays an important role for the defense purpose planning and strategies. 3-Dimensional geospatial data provides the details of object in depth, breadth, and height. Three-dimensional stereoscopic image evaluation and visualizations help to get qualitative and quantitative information about an object.3D visualization generation can be viewed from any angle which helps for analysis operations through scene-based or object-based and helps to quantifying object information. Further Machine learning techniques, data analytics, IoT and ICT infrastructure along with 3D geospatial data can play important roles in defining solutions that help to build and ensure the complex planning and chalk out the strategies. The aim of this project will be to develop very high-resolution accurate 3D model, orthophoto, DSM and other geospatial database for defense purpose and use it with 3D stereoscopic display along with hand tools for efficient planning and strategies in defense.

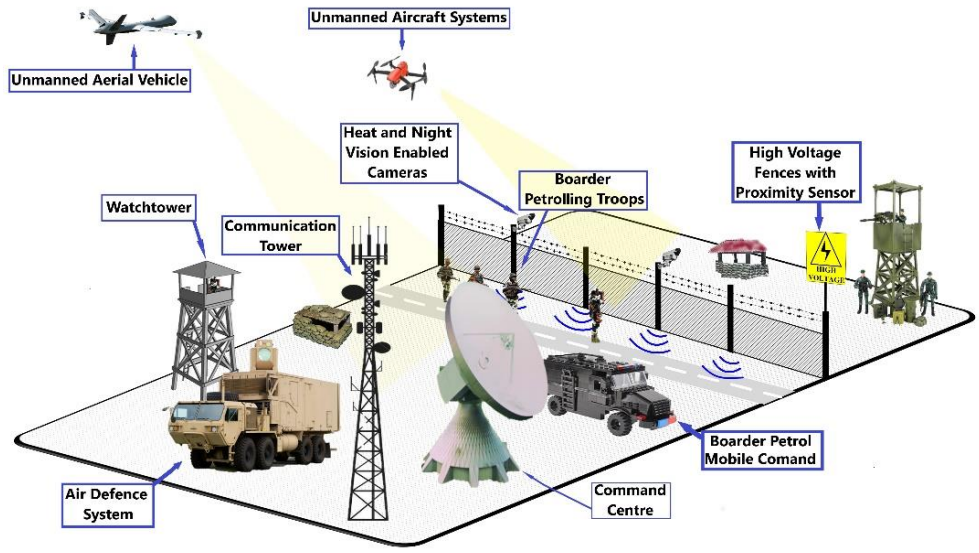


Fig. 1.8 Border surveillance system.

ii. Microwave techniques for imaging including object detecting radars

Through-the-wall microwave imaging is one of the important emerging microwave techniques in the recent years. Such an imaging system provides enhanced situational awareness in a variety of military applications. Such systems not only detect the presence of the targets behind

walls, but also provide information concerning each target's location, motion, size, and backscattering cross section. Many approaches have been attempted in testing through-the-wall radar imaging techniques. The most widely used approach is the wideband or UWB radar mechanism, which contains an antenna array, or one antenna measuring at multiple locations to form a synthetic aperture. The bandwidth covered is typically from a few hundred MHz to several GHz [Wenyi Shao and Todd McCollough, IEEE Microwave Magazine]. The backscattered signals are generally measured by all antenna elements in the array and are calculated to produce an image. Such systems are proposed in present DPR for imaging of hidden objects or objects behind wall.

iii. Stealth technique based on advanced polymer composites

Most of the airborne objects are prone to be detected by radars using the X and Ku frequency band of microwave. Considering the range, where the threat of detection is maximum, there is an emergent need for developing materials in which the absorption occurs in the frequency range of 1-20 GHz. The uses of ferrite as absorbing materials are becoming very significant. In addition to that Inherently Conducting Polymers (IPCs) are also finding their application as absorbing materials for electromagnetic radiation. These polymeric materials also provide processing ease for coating or application of materials for microwave (MW) absorption. However, IPCs suffer from other issues like stability and mechanical strength. Composites based on polymers like metal/polymer, carbon nanotube–epoxy etc. has been reported to overcome these issues. A possible solution is to employ IPCs with conventional polymers blend along with magnetic nanoparticles. The blend will provide extrusion possibility and ease in processing of materials and better distribution of nanomaterials in the polymer matrix with control on physical and structural properties. The metal oxide functionalized materials will provide excellent absorption and stability to the polymer (especially IPCs). Broadband RADAR absorbing advanced materials will be developed based on magnetic nanoparticles and Inherently Conducting Polymers.

iv. Power systems for operating sensors in remote areas

The defence vehicles need to be operated in adverse condition which requires batteries for electrical power support. To enhance the life and reliability of theses batteries optimal battery charging is very important feature to be taken care. There are several issues associated with battery charging for defence vehicles such as battery charging infrastructure, battery size, charging connections supported by the vehicles, capacity of power supply etc. An optimal

charger within a vehicle that can handle various charging profile will be necessary for future. Interdisciplinary Data Analytics and Predictive Technology will help in designing the optimal battery charging scheme for the defence vehicle. The DAPT based charger will increase the life of battery without increasing the weight, size and cost of the system by exploiting the existing electric traction motor and power electronics circuit. The data will be collected in from of various values of the voltage and corresponding current values in various charging states and conditions. These collected data will be used as look-up table, the analysis of which will be used to predict a model to design optimal charging control for battery.

v. Explosive detection

Sensitive detection of explosives is a challenge for army during the war as well as terrorist threats. Detecting explosives has also become a very complex due use of wide variety of materials as explosives and the lack of easily detectable signatures. Nanosensors have the potential to satisfy all the requirements for an effective platform for the detection of explosives. These sensors will be developed and signature for various explosives will also be developed for the defence.

vi. Smart sensors for soldiers (Air, Water and health)

Chemical sensors are major requirement of military due to continuous testing of environment. Testing of Air, Water and Solid materials including explosives are major requirement for military personals even they are not in war situation. These sensors are possible by development of miniaturised sensors like Lab-on chip and wearable smart sensors. FETs and Electrochemical sensor are getting attention in detection of toxic chemical and also biological materials (biosensors). In this are the major focus will be given on development of indigenous sensors and implantation for defence applications. The priority will be on Gas, Water and Food sensors for safety of military personals.

vii. Biosensors to know the readiness of soldiers

In view of bio-war and use of novel bacteria and viruses during the war the MEMS technology is showing enormous potential for detecting and recognizing biological materials. Among the miniature mechanical components that can be fabricated in MEMS are microfluidic components, such as tiny valves and pumps, which can be configured to create an integrated DNA amplifier based on the PCR process. Recently, we have seen the application of PCR in detection of Corona Virus (COVID-19). However, it was limited due to requirement of

conventional PCR and sophisticated lab. This will be addressed by using miniaturized system behaving like PCR or rapid detection kits based on antibody-antigen interaction.

viii. 5G for defence communications

Communication and exchange of data is very important and crucial in battle field. New war equipment need good data and in real time. Further, different kind of sensors will also be deployed for getting the different parameters of field. 5G technology can fulfil the said requirements. Therefore, it is desired to deploy 5G technology for defence purposes. But there are many challenges in deploying the 5G technology.

ix. Advance Polymer Composites

Soldiers need better protection against new ballistic threats and the overall weight of body protection is also required to reduce to increase the comfort of soldiers. Apart from these advanced materials are required for uniforms and tents of the soldiers to keep them warm at high altitudes and also escape from the radars of enemy. These issues may be addressed by development of novel polymer nanocomposites.

The above major areas of Interdisciplinary DAPT in Defence Research and Development will be focussed with following objectives:

i) To promote translational research in DAPT and associated technologies.
ii) To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.
iii) To enhance high-end researchers base, Human Resource Development (HRD) and skill-sets in these emerging areas.
iv) To enhance core competencies, capacity building and training to nurture innovation and start-up ecosystem.
v) To establish and strengthen the international collaborative research for cross-fertilization of ideas.
vi) To set up world-class interdisciplinary centres of excellence at IIT (BHU), that can become repositories of core expertise in DAPT and related areas and serve as focal points for technology inputs for the industry and policy advice for the government.

vii) To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects.

viii) To tie up with incubation centres and accelerators to foster close collaboration with entrepreneurship eco-system.

ix) To address some of the National issues and development of sector-specific solutions.

4) Road Transport and Highways

i) To provide a realistic environment for testing algorithms and systems used in ITS with the expected outputs of general purpose and comprehensive test facilities do not exist in India which limits research and modelling transportation activities and their impact on the economy and environment. With an autonomous system acting as an umbrella for all components, it is much easier to simulate and manage large scale models that respect existing scenarios.

ii) To standardize transportation data collection, data fusion and streamline storage and access to related databases with the expected outputs of tools to unify data collection from transportation infrastructure such that resource use for collection, storage and processing are minimized. This is essential for scaling up the data collection efforts to a larger area. In the absence of such unifying systems efforts for data collection and DAPT would not be utilized efficiently. Also, a lot of data is collected but is lying at scattered locations and is not being utilized except for aggregate computations. With the help of DAPT, more detailed analysis, modelling and predictions of trips (trucks, cars) can be done with much higher accuracy.

iii) To develop training materials and tools for learning, implementing and analysing ITS under Indian scenarios with the outputs of most training materials are not customized to Indian conditions and constraints making them less practical for implementation.

iv) To develop vehicle crash avoidance systems with the outputs of unsignalized intersections are traffic accident hotspots since road users have conflicting paths (competition for a spot at a given time instance) more frequently as they do not see the approaching vehicles or pedestrians. Low cost portable crash avoidance

systems consist of a list of systems that can be easily installed and maintained, are in demand and should therefore be easily available.

v) To develop emissions factors and emissions rates for Indian conditions and driving behaviours with the outputs of implementing appropriate policy and allocate resources appropriately, it is important to more accurately estimate the exhaust emissions given the vehicle types, age and fuel used. India can lead the developing world by developing.

vi) To model driver behaviour using naturalistic driving data with the outputs naturalistic driving study enables collection of various parameters using a sensors grid that captures the driving behaviour to predict future crashes or risky driving. There are no facilities or programs in India that performs this level of driver behaviour and traffic impact studies. Almost all studies are coming out of the developing world which cannot be used in Indian conditions.

vii) To develop pedestrian mobility and tracking system with the output of managing a huge amount of crowd especially under heterogeneous vehicle types is challenging. Modern pedestrian mobility and tracking system can take advantage of sensors.

5) Health and Family Welfare

One of the important areas of applications for Cyber-Physical Systems (CPS) is Health Care Technology. Particularly for Brain/Mind Health care is the area that would reap the maximal benefits, as this area has the maximum sickness and disability burden, covering neurological, muscular, intellectual handicap, and learning disorders, as well as mental abnormalities, addiction, road accidents, and birth injury.

The way to manage such ill-health, is to first identify which type of sickness or disorder is there (screening, testing or diagnostics), and then to control or manage the sickness (treatment, intervention or therapy). A most relevant issue pertains to both the fields of Diagnostic systems and Therapy Planning systems. Particularly for Diagnostic Systems, there is the critical need for development of Non-invasive screening technology, as now scanning, signalling or imaging systems are virtually universally available and can give a very accurate representation of abnormal structural and function of organs. Here a seminal requirement is to develop automated diagnostic or screening systems, as it is now

known that Machine Learning methods often outstrips the efficiency of diagnosis by a human interpreter.

Moreover, once the diagnosis is accurately known, the immediate next need springs to action. This is the requirement of treatment or management of the disorder diagnosed. Here, a most significant area, from the perspective, of Cyber-Physical System, is automated prediction of the most automated therapy protocol and selection of the therapeutic agent (drugs, physiotherapy, electrostimulation, pacing). This can be performed by formulating Medical Expert Systems and Treatment Planning Systems, using Artificial Intelligence principles. Such systems optimize the clinical efficacy of the therapy, as well as minimizing the side-effects and cost.

The focus of the Healthcare domain is amelioration, of Brain/Mind health (BMH) problems, particularly deliverables would be oriented to deal with neurological and psychiatric situations. As the aforesaid paragraphs delineate, by using readily available computing power, these neuroscience and biological technologies, can be well utilized to make much accurate screening and diagnostics, as well as select the most effective treatment approach while minimizing the side-effect or toxicities, thus considerably decreasing the expenses incurred, and readily accelerating the affordability. The major technologies involved are displayed in Fig. 1.9.

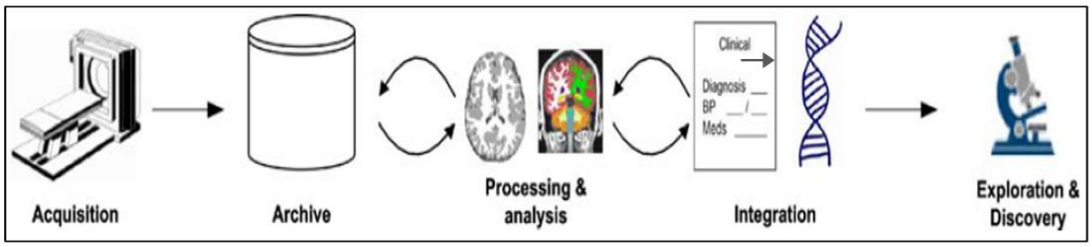


Fig. 1.9 Information transmission pathway in Healthcare System: here Data Analytics and Predictive Technology can enhance the efficiency of the Delivery System.

DAPT-BMH Mission would be interacting with the health set-ups or medical units across the country through the NIC-NET, Indian Digital Health Network or by NKN-NIC (National Knowledge Network, NKN-2). As per the practice prevailing in Health sector collaboration (e.g. Cancer Grid or Musculoskeletal Grid, GOI), the NKN-based interaction is facilitated zone-wise (east, west, north, south) by the NIC/CDAC office at the respective zones [Fig. 1.10]:

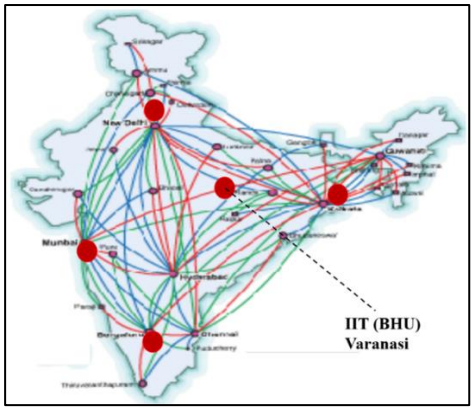


Fig.1.10: Data Transmission linkage between DAPT-BMH and Healthcare institutions across India. via facilitation of the four zonal units of NKN / Digital Health Net.

► *North zone:* NIC unit, AIIMS, New Delhi.

► *South zone:* NIC unit, National Inst. of Mental Health & Neurosciences, NIMHANS, Bangalore

► *West zone:* NIC unit, Tata Memorial Institute / KEM Medical College, Mumbai.

► *East zone:* NIC unit, Institute of P.G. Medical Education & Research, IPGMER, Kolkata

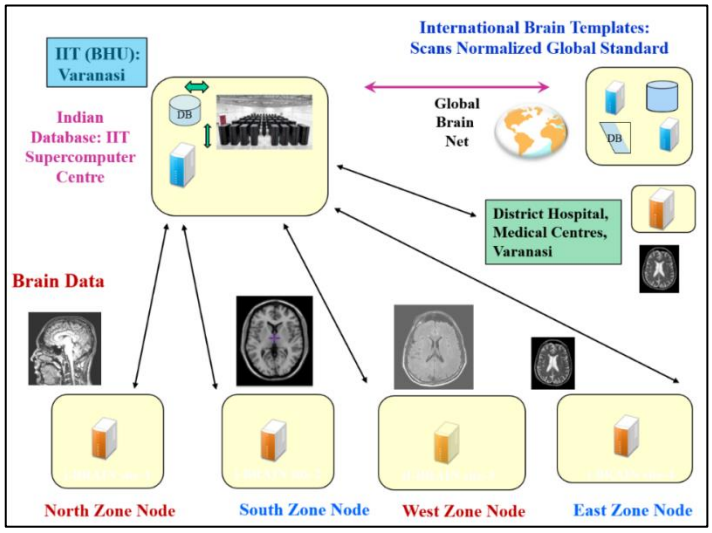


Fig. 1.11: Central data processing at National Supercomputing Mission, Varanasi Node, at IIT (BHU), with international collaboration via Global Brain Grid.

Fig. 1.11 shows the operative modality. As required data and images from these nodes, as well as that from Medical Institutions in Varanasi, could be accessed by DAPT-BMH at IIT (BHU) and computational analysis be performed at IIT (BHU) utilizing the facilities of:

- National Supercomputing Mission, Varanasi Node [at IIT (BHU)]
- Computing Service Centre, IIT (BHU) Computing Unit
- School of Bio – Medical Engineering, IIT (BHU)

If required, the Mirror site of this IIT (BHU) data set-up may be at NKN – Hyderabad, the NKN Hyderabad location serves as Mirror site of several other data systems.

The overall DAPT schema for Diagnostic and Therapeutic formulations is illustrated in Fig. 1.12.

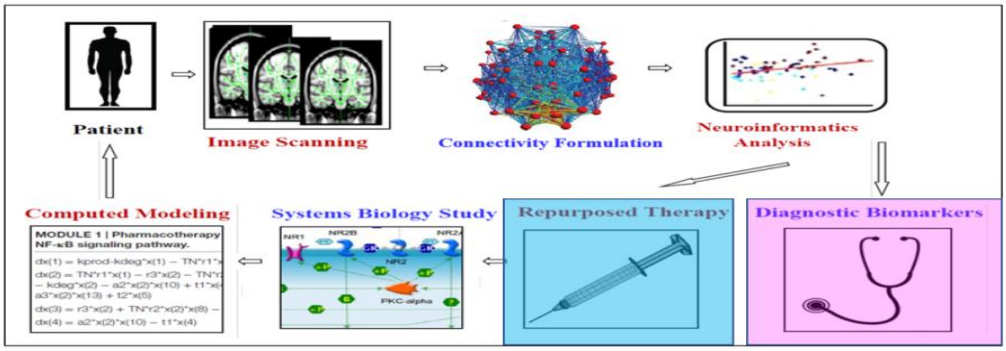


Fig. 1.12: Illustrative Schema for applying Data Analytics & Predictive Technology for developing Diagnostics and Treatment methodologies for Neurological diseases and Mental disorders.

There would also be interlinkage with the Global Brain Grid (European Union's NeuGrid, and International Brain Grid, facilitated by Canadian Govt's Institute of Health Research (at the Montreal Neuro Institute, McGill University, Montreal). This linkage would enable Indian investigators to perform globally-standardized clinical trials of the processes / products developed in India.

As mentioned earlier, a main focus of the health domain is to deal separately with age-wise conditions, and hence the objectives can be stratified as follows.

Table 1.1 Beneficiary Age Group and Objectives

Beneficiary Age-Group	**Specific Objectives**
Adult age-group: Amelioration of Brain Disorders by Predictive & Optimality Technology	**Neurological Outcome:** Development of automated screening methods and optimal intervention for Cerebrovascular health as Stroke and Vascular Dementia
	Psychiatric Outcome: Formulation of Causality Analysis formulation and preventive management of Acute Depression and its sequalae: Suicidal mentation.
Childhood age-group: Enhancing Brain Development & Learning by Digital Analytics	**Neurological Outcome:** Construction of digital methodology for Non-contact or minimally-contact prediction and management of asphyxia or chocking in infants.
	Psychiatric Outcome*:* Development tablet-based screening methods and optimize behavioral/cognitive intervention for remediation of Attention Deficit / Hyperactivity syndromes.

Elderly age-group: Computational Bio-engineering for assisting Disabilities	**Neurological Outcome:** Construction of smart Neuro-assistive devices for incontinence of Urinary bladder, and Rectal stool.
	Psychiatric Outcome: Patient-adaptive Monitoring and Stimulation Technology for maintaining or actuating cognitive and psychological reflexes, while ageing occurs.

1.2.3 Expected outputs/ Deliverables

The specific objectives and expected deliverables of the mission are given in Table 1.2.

Table 1.2 Objectives with expected deliverables

S. No.	Objectives	Expected outputs/ Deliverables
1	To promote translational research in DAPT on the identified five thrust/application areas and related technologies.	Increased core researchers base, Start-ups and spin-offs
2	To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.	A set of technologies, tools, algorithms to feed into some of the national priorities
3	To enhance high-end researchers base, Human Resource Development (HRD) and skill sets in these emerging areas.	Creation of next-generation technocrats, Scientists, Engineers, Skilled and semi-skilled workforce.
4	To establish and strengthen the international collaborative research for cross-fertilization of ideas.	Global standard Collaborative research for some of the India specific issues.
5	To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	Start-up companies, job creation and economic growth
6	To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	Enhanced participation of private industry in R&D, PPP model demonstration in technology development
7	To set mission mode application goals and foundational themes for excellence for different centers. Set up DAPT test beds at various centers.	Proven prototypes, national test beds for sector-specific solutions
8	To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system	Enhanced delivery mechanism
9	To address some of the National issues and development of sector-specific solutions.	Technologies to address some of the national issues.
It is important to mention that the NM-DAPT will become self-sustainable in a period of five years. The finances, administration, and R&D will be solely generated/managed by the IIT (BHU) within the framework of the Government of India guidelines.		

1.2.4 Sub-Missions or Programmes under NM-DAPT

Towards realization of objectives of the Mission in full measures, the implementation shall be through 5 sub-missions or Programmes.

1 **Technology Development** through expert-driven research, consortium-based mission-oriented research through cluster-based network programmes, directed research for the specific requirements of Industry, other Govt verticals and International Collaborative Research Programmes.

2 **Centres of Excellence**: Dedicated Centres to carry out domain-specific transnational research, training and capacity building, product, process and prototype development.

3 **HRD and Skill Development:** to generate next generation technologists and advanced skill development.

4 **Innovation, Entrepreneurship and Start-up Ecosystem:** To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.

5 **International Collaborations:** To establish and strengthen the international collaborative research for cross-fertilization of ideas.

1.2.5 NM-DAPT and National Priorities

NM-DAPT programme rightly fits into National initiatives like Sustainable Development Goals (SDGs), Digital India, Make-in-India, Industry 4.0, SMART Society 5.0, Skill India and Start-Up India. The DAPT Mission facilitates and caters to these national initiatives by developing sector-specific core technologies, human sources development and develops advanced skill sets and will feed into the Innovation and Start-up ecosystem of GoI. The following are some of the national priorities wherein DAPT has a role in their implementation and success.

1.3 Problems to be addressed

The centre on DAPT is committed to improve the DAPT based infrastructure in telecommunications, power, road transport and highways, defence research and development, and health and family welfare. The DAPT aims to address following issues related to power management in the Smart Cities Mission, Transportation, Healthcare, Intelligent Communication System, and Defence infrastructure of the Government of India. Some of the specific areas of work are as follows.

1) It gives a new concept of green and user-friendly smart hybrid (with customized ac and dc bus simultaneously) interconnected IoT based smart homes. One of the important features of the plan would be that the data from the distribution network and consumer side will be analysed. Based on the analysed data, a model would be predicted for dynamic load sanction to the individual smart homes. Thus, instead of a blanket/fixed load sanction each home will have sanction of dynamic load (with upper ceiling) as per their requirement. This will optimize the power distribution according to the generation.
2) The smart homes will act as digital data centres and requisite data from the input and load side will be used to predict the current and futuristic loads. The various node point data may be analysed to make the smart home a test bed.
3) It provides intelligent communication system.
4) It gives intelligent and smart transportation system that includes highway asset management and prediction, driver behaviour research centre, freight demand modelling, parking demand prediction and monitoring system, smart pedestrian navigation and mapping system, and indoor mobility mapping system.
5) It provides state of art healthcare with the use of DAPT.
6) IIT (BHU) is a knowledge partner is UP Govt defence corridor. It will help improving defence infrastructure of the country with the state of art DAPT.

1.3.1 Application Problems

There are numerous problems which can be addressed through the centre on DAPT. Some of the application areas for mission mode execution can be made based on prioritized needs of the country, and the interests of the various stakeholders and industry.

(1) Intelligent Energy Systems and Smart Grids
(2) Intelligent & Compassionate Cities
(3) Internet worked Mobility Systems
(4) Intelligent Transport Systems
(5) Advanced manufacturing
(6) Satellites networks for defence and civilian applications
(7) Autonomous drone systems for surveillance, security, logistics, transport
(8) High-quality Healthcare diagnostic, prognostic, and therapeutic systems for everyone
(9) Autonomous drone systems for farming, surveillance, security, logistics, transport

(10) Traffic and Connected Mobility Systems

(11) Advanced manufacturing

(12) Applications in Defence Sector

1.3.2 R&D Problems

The tree diagram shown below in Fig. 1.13 gives some of the R&D problems related to the five identified thrust/application areas.

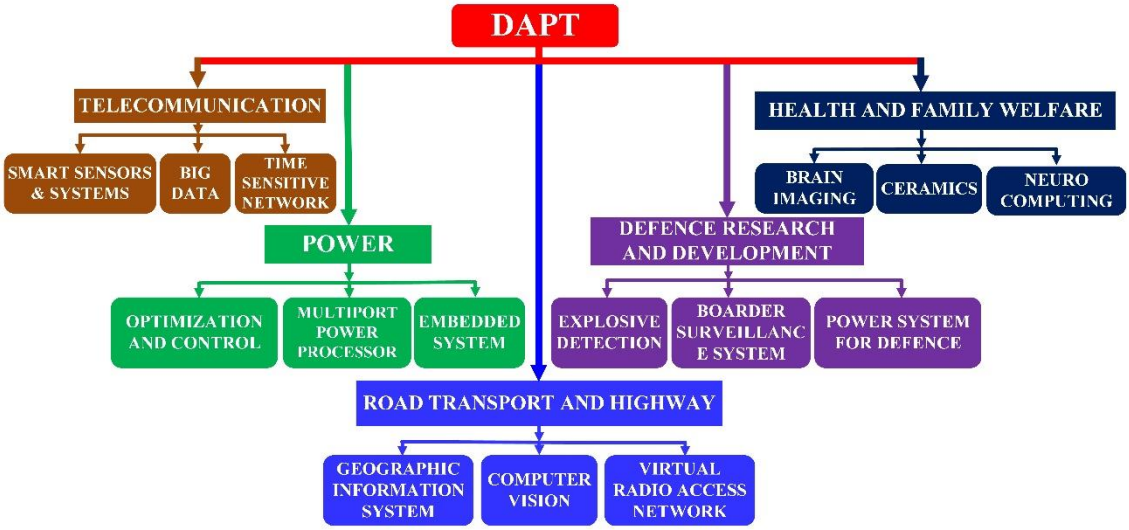


Fig. 1.13 Tree diagram for R&D problems related to the identified thrust/application areas.

1.3.3 HRD and Skill Development

DAPT is a disruptive technologies and technology-driven system. It may pose unemployment once complete automation is undertaken. At the same time, it provides an opportunity for job seekers to create job avenues in highly skilled areas. DAPT is a global phenomenon and it operates on fusion of technologies. Therefore, India should concentrate on an interdisciplinary approach and develop cross-cutting fusion technologies. Thus, the proposed programme aims at providing the state-of-the-art training and capacity building for creation of next-generation technocrats, engineers and scientists. It will address at various segments of education system like graduates, postgraduates, Doctoral, post-doctoral, skilled and semi-skilled segments. NM-DAPT aims at addressing most of the HRD issues in a holistic manner preparing the country for the next technology revolution.

1.3.4 Translational Research

India has the highest number of researchers and developing technologies which have potential in the industry. But it operates on watertight compartments and silos. There is a requirement to bring in a middle order structure which translates the academic R&D into technologies to

industry. NM-DAPT mission which proposes the creation of Centre of Excellence basically aims at translational research that is converting the academic research into industry-oriented technology.

1.3.5 International Collaboration

The advent of networking has made the world a global village. Innovations happening across the globe are not only affecting the global economy but also the global skill. Therefore, catching the international development is the need of the hour. International collaboration and collaborative research proposed by DAPT aim at bringing the global research paradigms and connecting to the Indian researchers.

TABLE: 1.3 International research institutes

Name	Website	Remarks
CMU (Carnegie Mellon University)	https://ai.cs.cmu.edu/	Focus on Autonomous vehicles, robotics, AGI, Speech and computer vision
Open AI	openai.com	OpenAI is a non-profit AI research company, discovering and enacting the path to safe artificial general intelligence.
University of Oxford	http://www.cs.ox.ac.uk/research/ai_ml/	Focus on computer vision and Artificial General Intelligence
Montreal Institute for Learning Algorithms (MILA) and the Institute for Data Valorisation (IVADO)	https://mila.quebec	Focus on fundamentals of Artificial Intelligence, AGI, Speech and vision
Stanford University	http://ai.stanford.edu/	Focus on Autonomous vehicles, robotics, AGI, Speech and computer vision
University of Toronto	https://www.utoronto.ca/news/tags/artificial-intelligence	Focus on Autonomous vehicles, robotics, AGI, Speech and computer vision
Virginia Tech, Blabsburg, Virginia, USA	https://www.vt.edu/ /	Coordinates activities across the universities for DAPT mission
Concordia University, Montreal Canada	https://www.concordia.ca/	Focus on Autonomous vehicles, robotics, AGI and computer vision
University of Minnesota, Twin Cities	https://datascience.umn.edu/	
University of Minho, Portugal	http://www.civil.uminho.pt/transportinfra/index.htm	Pavement Management Systems
The University of Michigan Transportation Research Institute	http://www.aacvte.org/	Ann Arbor Connected Vehicle Test Environment

University of Sydney Intelligent transport systems	https://www.sydney.edu.au/engineering/our-research/robotics-and-intelligent-systems/australian-centre-for-field-robotics/intelligent-transport-systems.html	Robotics and ITS
National Technical University of Athens, Greece	http://www.transport.ntua.gr/home	Road Safety and ITS
The Intelligent Transportations Systems Joint Program Office Department of Transportation, USA	https://www.its.dot.gov/	ITS and Autonomous Vehicle
University of Toronto Transportation Research Institute	https://uttri.utoronto.ca/research/new-research-areas/level-2-intelligent-transportation-systems/	ITS Research
Hankuk (Korea) University of Foreign Studies (HUFS)	http://www.hufs.ac.kr/user/hufsenglish/gra_1.jsp	ReSENSE Lab Centre for Intelligent Systems Design
MtoV Inc. South Korea	http://www.mtov.net/	IoT based Hardware/Software Automotive
Yonsei Institute of Convergence Technology, School of Integrated Technology, Yonsei University, South Korea	https://www.yonsei.ac.kr/en_sc/index.jsp	Smart Systems Lab
Woosong University, Jayang-Dong, Dong-Gu Daejeon, South Korea	http://tech.endicott.ac.kr/main/index.jsp https://reblockchain.tech/	Blockchain Research Group
Swanson School of Engineering, University of Pittsburgh	https://www.engineering.pitt.edu/	ITS Application in Urban Areas
National Technical University of Athens, Greece	http://www.transport.ntua.gr/home/	Road Safety and ITS
Road Safety Institute, University of Minnesota Twin Cities	http://www.roadwaysafety.umn.edu/research/areas/connected/	Road Safety and Connected Vehicles

DAPT Week is an annual marquee event which collocates 5 conferences related to DAPT. In addition, ACM and IEEE have also created new journals for DAPT. There are numerous IoT conferences worldwide and as we discussed earlier - there is a significant overlap of IoT and DAPT. Apart from this, major conferences include NIPS (Neural Information processing

systems) ICML (International Conference on Machine Learning) and AAAI (Association for the Advancement of Artificial Intelligence).

1.3.6 Innovation, Entrepreneurship & Start-up Ecosystem

The international novelty standard operates in a cycle wherein innovative ideas are funded to generate prototypes and get patents leading to a series of start-ups. Established industry players lookout for technologies through patent portals however, this paradigm is loosely operating in India. An analysis of International Patents data will be the huge problem that India is facing in the area of monetization of innovations.

(a) Patent Landscape analysis in DAPT and related area

The status of the patents in the predictive data analytics and data analytics is discussed in this section. Fig. 1.14 shows the percentage distribution chart of the patents in the field of predictive data analytics and subsequent Table 1.4 shows the top ten companies who published patents in this area. It may be observed that the maximum number of patents was obtained between 2013-16. Power Analytics Corporation, USA has the maximum number of patents in the field of predictive data analytics with an overall percentage of 4.40%. Similarly, Fig. 1.15 shows the percentage distribution chart of patents in the field of data analytics and Table 1.5 shows top ten companies for this. It may be observed from Fig. 1.15 and Table 1.5 that maximum number of patents obtained from 2013-19 with International Business Machines Corporation, USA being on top of the list with an overall percentage of 5.20%.

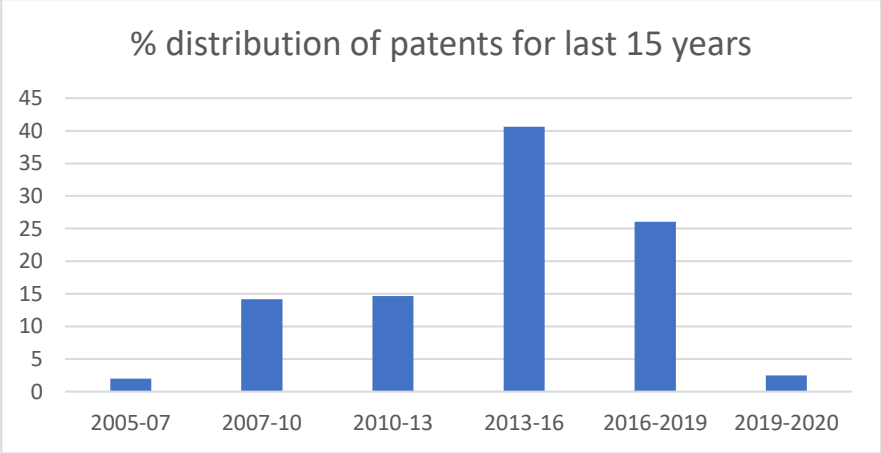


Fig. 1.14 Percentage distribution of patent in predictive data analytics.

Top ten companies publishing patents in the field of predictive data analytics are given in Table 1.4.

Table 1.4 Top ten companies publishing patents in predictive data analytics

Power Analytics Corporation	4.40%
Fisher-Rosemount Systems, Inc.	3.90%
Somos, Inc.	3.20%
Edsa Micro Corporation	3.10%
Uptake Technologies, Inc.	2.90%
International Business Machines Corporation	2.90%
Salesforce.Com, Inc.	2.50%
Qualcomm Incorporated	2.10%
United States Postal Service	1.80%
Rockwell Automation Technologies, Inc.	1.40%

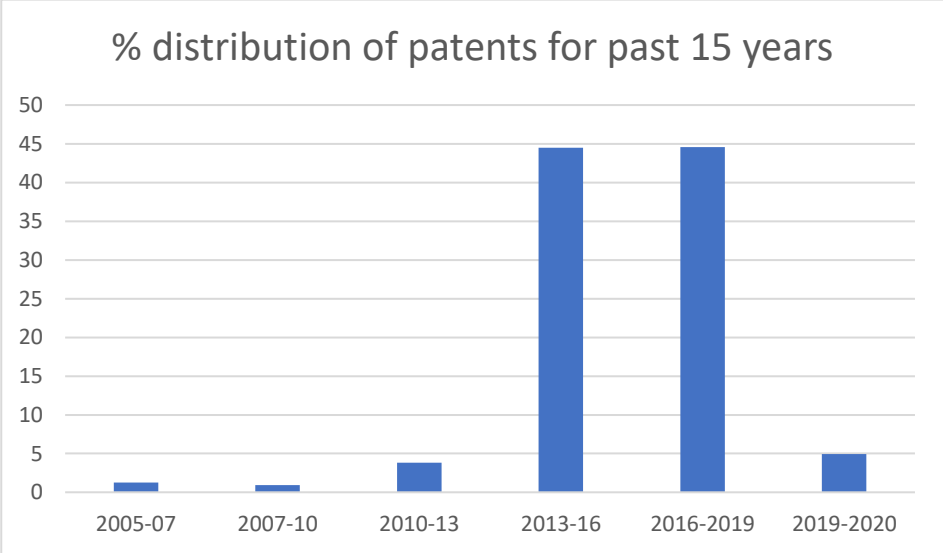


Fig. 1.15 Percentage distribution of patent in data analytics.

Top ten companies publishing patents in the field of data analytics are given in the following Table 1.5.

Table 1.5 Top ten companies publishing patents in data analytics

International Business Machines Corporation	5.20%
Cognitive Scale, Inc.	3.40%
Strong Force Iot Portfolio 2016, Llc	3.10%
Fisher-Rosemount Systems, Inc.	3.10%

Somos, Inc.	2.60%
Splunk Inc.	2.60%
Rockwell Automation Technologies, Inc.	2.10%
Huawei Technologies Co., Ltd.	1.90%
Strong Force IoT Portfolio 2016, LLC	1.70%
Uptake Technologies, Inc.	1.60%

(b) Current status of DAPT in India

The IITs and some of Central/ State Universities have been researching in various fundamental and applied aspects related to DAPT, especially in the areas of controls, hybrid systems, AI, data science and wireless sensor networks. Some industries such as Tata Consultancy Services Ltd, Cognosante Holdings Llc, Dassault Systems Simulia Corp and Dassault Systems, Fraunhofer GesZurFörderung Der AngewandtenForschung E V Cognosante Holdings Llc are also working on DAPT or the areas related to it. As of now, three patents from Indian organizations in the field of predictive data analytics and five on predictive technologies have been obtained. However, there is a lack of a coherent view on DAPT as a discipline and there is a dearth of dedicated interdisciplinary collaboration centres on this. Hence, most of the researches are still being done in silos, whereas true progress in DAPT, especially on the applications front, will only emerge via interdisciplinary collaborations. Moreover, a lot of DAPT researches are either theoretical or confined to small experimental and system development work at the laboratory level prototype. In order to broaden the spectrum of DAPT research, involvement of multidisciplinary and multi-institutions teams that are given a mission to address a specific problem over a given time frame is the need of the hour.

(c) Gap Analysis

This outlines specific steps to take to fill the gap between its current and future states and reach its target objectives. The analysis provides a basis for predicting research and development future trends and helps policymakers manage technology changes that will result from DAPT.

Gap 1: Collaborative/interdisciplinary approach

Presently DAPT researches are being done in silos in various departments in academic institutions. It is truly a need to study such systems holistically and hence motivates the need for an interdisciplinary approach.

Gap 2: System level experimental validation

DAPT as a distinctive area makes sense when the scales of the systems are large and experimental validation of ideas/theories/technologies at large scales - is a skill to be mastered. The institutional/ university research is largely restricted to theoretical or laboratory scale due to various constraints. Enabling pilot/large scale testbeds/laboratories are critical missing piece in DAPT research and anything done in this will be a great value addition.

Gap 3: Output to outcome conversion

DAPT application projects need to have all the stakeholders on board from the beginning. The views of the stakeholders regarding what application problems to focus on will be of great importance to ensure practical applicability of the research. Involvement of "technology translators" at an early stage, e.g., entrepreneurs/agencies/companies which can convert the research technologies to commercial products should also be looked into. In this way, a truly hybrid approach, via collaboration centres, might need to be evolved.

Gap 4: Mission mode project management capabilities

In the academic institution, researchers usually work best individually in a small team of students and research group. However, large-scale mission mode experimental projects will necessarily involve large teams and multiple interdependent tasks. Effective project management of these mission mode projects are critical to ensure a good chance of DAPT success at large.

Chapter-2

Mission Beneficiaries

2.1 Stakeholders Consultations

India as the largest global market brings golden opportunities to its stakeholders viz. the research institutions, industries and entrepreneurs. DAPT is one of such areas which have infinite scope to revolutionise the whole industry and our society. DAPT is now most sought after in every area to increase the productions and performance by 100 folds. It is the time to make DAPT known to everyone and to enable them to harness its possibilities in every way, may it be research, technology development or innovation. DAPT is the goldmine for innovative solutions and products. Indian business & industry as well as the Government's agencies viz. R&D and academic organisations of national importance have the potential for DAPT development and subsequent industrial and societal adoption. IIT (BHU) while mounting the national mission on DAPT, understands the importance and possibilities of these technologies and will take forward lead in dissemination and adoption of its products and solutions in the global markets in a well-structured and concerted manner to generate and channelize the resources and efforts to exploit and leverage the possibilities of using DAPT in the country. In addition, the DAPT domain of the country is almost every sector of Indian society and walk of life, in it's divergent fields. To handle the enormous task of preparing a strategic roadmap for this Mission, consultative approach resorted and same was adopted with an objective.

(i)To evolve models for promoting and fostering DAPT and applications in the country.
(ii)Assess the present status of the industry in terms of market size, different players providing services across sectors/ functions, opportunities, SWOT analysis, policy framework, present skill levels available etc.
(iii) Market landscape survey to assess the future opportunities and demand for skill levels.
(iv) Gap analysis in terms of HRD.
(v) Evolve a strategic roadmap and micro-level action plan clearly defining roles of various stakeholders: government, industry, academia, industry associations and others with clear timelines and outcomes.
(vi) The international scenario examined while evolving strategic roadmap.

2.1.1 Stakeholders Engagement

To make this Detailed Project Report comprehensive so that the Mission objectives are realized in full measures, it was decided to anchor it in the aspirations of stakeholders,

champions and enthusiasts of DAPT, across the world, especially IIT (BHU) industrialists, alumni, researchers and students, who would be the key drivers of the new revolution. Accordingly, a consultative framework was conceived- both through face-to-face interactions and over the internet. Interactions with experts from academic, R&D, industry and government institutions were also carried out through on-line interactions.

(A) Methodology

The methodology adopted for the study was two folds that are primary research and secondary research.

(a) Primary Research

The primary research consisted of obtaining feedback from the national consultative meetings/workshops, and suggestions from the Stakeholders. An open-ended debate was carried out across the prospective stakeholders of DAPT to collect insights/ foresight/ ideas and integrate them into this DPR. In all nine technology verticals were coined, seeking inputs in the areas for research and development, human resource development, innovation, entrepreneurship, start-ups, Centres of Excellence, international collaborations etc.

Suggestions and feedback received from the stakeholders during the consultative meetings are presented in following sections:

i. National Mission on DAPT

- We will have DAPT developed, responsive to the needs of our country which has a huge working population that has to be provided jobs. Therefore, it would be necessary to understand the challenges for India, the potential for application/intervention of DAPT therein and deliver the solutions on the ground, to benefit the people.
- We shall have to reach out to institutions and industry in a big way, even those overseas- to develop and implement these systems. We must act swiftly and gain the technological edge in this area, at a global level.
- Linkage of R&D with entities who work for technology commercialization is needed to be included in this mission. For sustainability of CoE in long-term (for further operation), there will be the key criterion before selection. This is possible only if there is a substantial contribution from industry which must gradually increase over a period.

- As this mission is multidisciplinary, therefore, three approaches can be used such as problem-centric approach, tool-centric approach and mixed approach to bring different stakeholders together for deep R&D in CoE. In the tool-centric approach, R&D is driven by developing multiple tools for the problem domain, whereas the problem-centric approach is driven by developing one tool for many application areas. In this DAPT mission, it is best suited to ensure a mixed approach, because of the multidisciplinary nature of the Data Analytics and Predictive Technologies based systems.
- It is not possible for solving all problems of India like poverty, water, unemployment, health, etc., and the focus will be sharply on selected technology areas that provide solutions which have mass impact on the society. Accordingly, FIVE thrust/application areas were chosen viz. Smart City Verticals: Smart Energy & Power, Intelligent Transportation & surveillance, Healthcare and family welfares, Intelligent Networks & Communication Systems and DAPT applications on Defence Systems mainly border security, real-time monitoring of soldier's physical and mental health and smart sensors related to air, water and food.
- Standardization of DAPT related technologies is needed covering three aspects- Hardware, Communication, and Human. DPR also covers related human standards in addition to the other two. We have to couple the already existing standardizations such as Machine to Machine which are in public domain, in the mission.
- The aim of Mission is also to create more human resource trained in DAPT in consultation with industry so that industry will accept it and make both side gains.
- Basic needs of the society be formulated as real-time problems and treated as objectives in DAPT for example Smart City, Power supply and management, Health, Communication, transportation and smart sensors.
- There is a need to facilitate collaboration and extend financial support to individual researchers and small industry R&D groups to bring them into mainstream research
- Establish sub-centers for R&D and to give opportunities to students and faculty in remote tier-II & tier-II institutions without proper resources.

- Demonstration Centres will be established under the Mission that can provide hands-on-training to students, entrepreneurs, start-ups, and MSMEs, on core DAPT technology and the application framework so developed. They can also be used as common prototyping and testing facilities.
- R&D areas identified will be aligned with the National Mission and mandatory be output driven.
- Programmes that promote cross-disciplinary collaborations, like Engineering, Medical, Defence, Societal fields will be launched under this mission.
- Some prize money/ reward/ incentive will be introduced for excellence in competitive R&D. Competition in R&D will drive towards a high quality of deliverable outputs (product or idea). DAPT is not new, and a lot of technologies already there on the shelf will be used to develop further applications. The approach could be to identify the readiness level (or maturity) of different technologies in DAPT and support them rather than support initiatives start from scratch.
- India will be a deficient country in next twenty years in term of water, mass transport, education, energy, security, etc. These deficiencies will be overcome through DAPT based solutions.

ii. Technology Development

- Open source platforms will be created for testing of prototypes, to drive the research on DAPT, towards translation. Data (Repository) sharing policies will be formulated for rudimentary data gathering, sharing and fair usage from every possible source (agencies, industry, government, etc) example: retail data from telecom services. A cloud-based platform/ repository of data will be developed that can be used freely by different agencies working on DAPT based products/ services. Example of such repository is NEON. An open platform will be extended to researchers working in this area to communicate with each other to overcome the hardships in the process of research. It will also help to find a solution to the common problem in the DAPT and related area because there is a chance that the hurdles in one research can be a strong pillar for others research. Open information portal for UG/PG students for technologies open for research/project by the government. A portal/platform for industry-academia-Government to share the problems faced by each other.

- Assurance is a performance metric of a system that includes safety and reliability (to give correct results) and is very much needed from DAPT system, as they work on the core. Towards this, investment in STQC (Standardization, Testing and Quality Certification) is required.
- System security is of utmost importance for the technologies deployed. Suitable protocols and standards will be formulated for secure DAPT implementation and functionality.
- Major thrust/application areas of R&D will be focused on Smart City Verticals: & Power, Road Transport and Highways, Healthcare & Family welfare Systems, Telecommunications and DAPT applications on Defence Systems. At least top 3 industries will be identified for end-to-end research and deployment (not stopping at development). DAPT is well suited for predictive as well as preventive maintenance and may also finds huge application in other sectors like railways, water, waste, gas, drainage system monitoring and waste management.
- There will be approaches/ incentives identified to catch the students young and train them on DAPT skills based on industry needs.

iii. Centre of Excellence (CoE)

- CoE will focus on research covering all aspects of technology life-cycle - research, technology development, translation, and management. CoE will be funded to excel in verticals (application areas) to be useful to the society; in the process, they will also develop the horizontals (core areas) too.
- Full-time managers/faculty will manage CoEs. In a CoE, the academia, industries, government and user agencies will be working together side by side. CoEs will have a hub-and-spoke architecture- that allows other academic institutions, research institutions, industry, industry associations, SMEs to plug in.
- Some suggestion on areas for CoEs to focus on: Smart City Verticals: Smart Energy & Power, Intelligent Transportation & surveillance, Ubiquitous Healthcare Systems and Intelligent Networks and Communication Systems and DAPT applications on Defence Systems like Drone Systems for border security, Body Area Networks for real-time monitoring of soldier's physical and mental health and stamina and beyond apart from working on Public Distribution

services, Healthcare analytics/ management, Networked automated systems, security, Manufacturing (including manufacturing of biopharmaceuticals), Dependable predictive/ warning systems, Disaster monitoring and prediction. DAPT will be aggressively used to solve water problems, energy problems, and sanitization that can impact a large segment of the population. 3-D printing is a huge prompt for DAPT technology. 3-D printing, required for customizing solution will be facilitated through CoEs. Some suggested areas are- safe and energy efficient logistics, driverless cars, that may be considered from exploration.

- CoE will be based on cluster model approach with all stakeholders participating and benefitting from it. Tier II and Tier III colleges and polytechnics will be allowed to be the part of the CoE, as spokes that reach out remote locations and address local problems.
- Intellectual Property rights are often contentious issues which the industry would like to clarify before they are asked to participate in CoEs. Ownership of IP will be given to the hosting Institute of CoE. The DPR will provide a basic minimum guideline on IP sharing which can be modified as per the needs of industry. IPR sharing is a big stumbling block in projects involving industry; these will be addressed in the DPR itself and will not be left to CoEs. Institutions being considered for the support that lead to IP generation must also be funded for international patents.
- Test-bed facilities for testing solutions/prototypes must be created on Smart City Verticals: Smart Energy & Power, Intelligent Transportation & surveillance, Ubiquitous Healthcare Systems and Intelligent Networks and Communication Systems and DAPT applications on Defence, along with a large number of innovative ideas which die in the absence of business models that can be the pull-factor.
- Conclave for CoE once in a year will be organized to discuss the problems faced, future challenges and possible solutions by each, to benefit collectively.
- There will be an awareness/training programmes in DAPT and related areas for government officials and working personnel who are not able to understand the jargon in the context of DAPT national mission.

iv. HRD & Skill Development

- CoE will try to introduce a scheme on the lines of Visvesvaraya Ph.D. and Pradhan Mantri Scholarship Schemes exclusively for research in DAPT. Under this programme, Industrial Organizations of the country will get an opportunity to collaborate with academic institutes of their choice for Research & Development and to produce skilled Ph.D. candidates in the areas of their interest. The fellowship amount will be on a higher side than other schemes and will be kept highly competitive. High-value PG and Doctoral fellowship jointly with Industry (like Microsoft, Ericsson, and Siemens) will be started. Special fellowships for M.Tech. students, specializing in DAPT will be introduced. A fixed number of fellowships per year under DAPT project will be created for PG/ Ph.D./JRF/SRF/PDF level.
- International/ national level symposium on DAPT will be conducted every year.
- Tier II & tier III engineering colleges will be considered for a role in the Mission. They could be considered for funding joint projects and setting up common facilities that can enhance the learning experience of the students. Thematic Faculty Development Programmes for tier II & tier III institutions must be introduced, so that students in these institutions can be encouraged to take up projects and research in DAPT.
- Organization of Summer schools on DAPT, for faculty and researchers, will be considered.
- Curriculum development will be taken up by focussed groups and involving industry. A balanced content with fundamentals and modern paradigms of DAPT will be taken into consideration. Workshops will be supported for curriculum development. The workshops and courses will be focused on device networks, machine learning, data analytics etc. with a compulsory field-oriented project on the identified thrust/application areas.
- The dearth of qualified people to teach topics/subjects in an evolving area like DAPT is imminent. To tide over the shortage, finishing schools will be introduced and funded. Industry person can develop faculty & curriculum inputs; Faculty from industry can be involved in teaching courses.

- The training programmes in DAPT will be of high quality and rigorous and lead to high- value certification.
- Industry must be involved in designing courses or modifying the existing programmes. The industries will be asked to give projections on the requirement of human resources that are specialized and skilled in DAPT.
- Online contests and hackathons for students (individual/group) will be organized as part of the Mission, to bring forth innovative ideas/ approaches/ models. Start innovation clubs in schools/ colleges challenge the students and offer incentives to encourage their participation in large numbers.
- Certification Courses Master and PhD levels will be initiated by entities which will be considered for imparting training, skilling and entrepreneurship programmes, whether by academia, institutes or industry. Institutions will initiate certificate programmes for skills; certificate could be jointly awarded with Industry/industries Association and DST.
- A scheme will be designed to support small projects from Govt. /Academic Institutions for 2nd/3rd year UG students. UG students will be given some credits/certifications, with fellowships for spending their time on the project under CoEs. Industry supported 6 months internship 4th year of UG courses under the CoE.

v. Innovation, Entrepreneurship & Start-up ecosystem

- Start-up funding will also be encouraged under CoE. Funded projects will be asked for plans for the deliverables from the project. At the end of the project, there will be at least 1 or 2 major global level startups coming out of the project. Industry-academia- Government (DST) collaborative incubation center will be set up.
- Internship for engineering students as teaching assistants for “tinkering labs” for High Schools. Skill development through internship/ training for the large duration on practical problems which will have social impacts. Incorporate entrepreneurship education/ training into the curriculum. Education ecosystem requires introduction of new courseware and faculty development
- Define end use cases/ pain areas and invite start-ups to develop solutions.

- Pre-incubators to facilitate professional teams to work with the university faculty on executing pilot-scale research projects. Technologies from these pilot projects could get commercialized by these teams at start-ups. Free incubation support from industry to candidates. Invite the participation of interested people to start the start-up, and take advantage of all incubation center from different industries under some scheme by Government.

vi. International collaborations

IIT (BHU) has signed MoUs with many reputed universities/institutions abroad (list enclosed) which could be roped in to become active research partners in the proposed TIH.

Table 2.1: International Collaborations

S. No.	Name	Collaboration Type
1	Virginia Tech, Blabsburg, Virginia, USA	Research and Development
2	Concordia University, Montreal Canada	Research and Development
3	Tokyo Institute of Technology, Japan	Research and Development
4	Kyushu Institute of Technology, Japan	Research and Development
5	Max Plank Institutes, Germany	Research and Development
6	University of Mainz, Germany	Research and Development
7	University of Cologne, Germany	Research and Development
8	Penn State University, Pennsylvania, USA	Research and Development
9	Purdue University, West Lafayette, Indiana, USA.	Research and Development
10	University of Iowa, Iowa City, Iowa, USA	Research and Development
11	Oklahoma University, USA	Research and Development
12	University at Buffalo, USA	Research and Development
13	Association of Swiss Universities of Applied Science	Research and Development
14	University of Illinois, Chicago	Research and Development
15	KTH University, Sweden	Research and Development
16	Missouri University of Science and Technology, Missouri, USA	Research and Development
17	NTU, Singapore	Research and Development

18	Melbourne Institute of Technology, Melbourne, Victoria, Australia	Research and Development
19	Florida International University, Florida, USA	Research and Development
20	Manufacturing Enterprise Solution Association, USA	Research and Development
21	Cambridge University, UK	Research and Development
22	University of LEEDS, UK	Research and Development
23	Cranfield University, UK (3 D- Printing)	Research and Development
24	Fraunhofer Institute for Systems and Innovation Research, Munich, Germany	Research and Development
25	Berkeley Artificial Intelligence Lab	Research and Development
26	University of Oxford, UK	Research and Development
27	University of Toronto, Canada	Research and Development
28	Texas A&M Transportation Institute	Research and Development
29	Minnesota Traffic Observatory	Research and Development
30	University of Pittsburgh, USA	Research and Development
31	Iowa State University, USA	Research and Development
32	Michigan University, USA	Research and Development

Moreover, many institutions have already given their consent to become research partner in the project as shown in Table 2.2 below.

Table 2.2: International Collaborations for NM-DAPT

S. No.	Name	Website	Remarks
1	Hankuk Korean University of Foreign Studies	http://www.hufs.ac.kr/user/hufsenglish/gra_1.jsp	ReSENSE Lab Centre for Intelligent System Design
2	MtoV Inc. South Korea	http://www.mtov.net/	IoT Based Hardware/Software Automotive

3	Yonsei Institute of Convergence Technology	https://icons.yonsei.ac.kr:4436/centers.php?mid=n03_01	Smart Systems Lab
4	Woosong University	http://english.wsu.ac.kr/main/index.jsp	Block Chain Research Group
5	Concordia University Motreal, Canada	https://www.concordia.ca/	Smart Power Processor Designs, Digital and Optimized Control Power Flow
6	Wasington State University	https://wsu.edu/	Smart Grid, DAPT based Demand Response Management
7	University of Victoria Canada	https://www.uvic.ca/	Machine Learning and DAPT for Smart Grid Architecutre
8	Kyushu Institute of Technology, Japan,	http://www.kyutech.ac.jp/english/	Sensors and Biosensors and AI.
9	Tokyo Institute of Technology, Japan	https://www.titech.ac.jp/english/	Devices and AI

(b) Secondary Research

Secondary research involved capturing relevant information from public domain through research articles, published documents on DAPT, Net Search, etc. Large number of research papers, reports, books, other public domain documents, and presentations are studied including DPR of DST (TIFAC) on ICPS. A list of the materials referred has been included in the Bibliography given in the report. An organized and structured thought process as given in DPR of DST (Table 2.3 below) was deployed to pick relevant information.

TABLE 2.3: Strategic Thought Process

Major Strategic Thought	Contributing Factors	Mapping with The Objectives of The Study
DAPT and its supporting areas	Understanding DAPT Defining DAPT Driving value from DAPT How to approach a DAPT project	Assess the present status of DAPT and its role & potential in R&D, the business & industry
Assessment of the current status	Major stakeholders, Availability of technologies The current and future technologies to be used, Adequacy of the available infrastructure, Quality & quantity of manpower available, Available Technologies & Providers	New computation Paradigm, Assessing the present status
Opportunities, threats, Gaps and questions	Where and how do we start? How do we create a business case for a pilot? SWOT Analysis What data is relevant?	SWOT Analysis, Market landscape survey to assess the future opportunities and demand
DAPT and The Global Scenario	Successful applications of DAPT DAPT for Development DAPT Market	The international scenario for evolving strategy for India.
Identification of the Pillars of Information Driven R&D, Governance and Business Transformation	Identification of the Business Drivers Doing more with the data – using DAPT and Business opportunities The aims of deploying an enterprise hubs	DAPT Applications Evolve a strategy and micro level action plan defining roles of various stakeholders
Maturity Stages on Road to DAPT	Initiate – Kickstart & build first success Scale up - Build confidence in sustainable success	Training & Capacity Building DAPT Road Map Entrepreneurship
Leveraging DAPT for Scientific Research & Development	Applications in R&D projects Establishment of Center for Excellence in DAPT Dissemination of DAPT knowledge Capacity Building through Training programme	Indian Perspective Identify Gap Areas Challenges in R&D for S&T Gap analysis in terms of skills levels and policy framework
Digital India	Provisions under Digital India Initiative Leveraging provisions under 'Digital India' Leveraging DAPT Synergy with e-Governance initiatives	Evolve a strategy and micro level action plan defining roles of various stakeholders Integrating Government Ministries
Data Demand Trends	Identify Gaps in roles and skills Gap Closing – Center of Excellence, Skilling/Upskilling, Training Programmes, Workshops at various levels of stakeholders	Gap analysis in terms of skills levels and policy framework

Managing the governance issues of DAPT	The regulatory context Privacy law as applied to DAPT Responsible DAPT business practices R & D Projects	DAPT Policy Perspective Evolve a strategy and micro level action plan defining roles of various stakeholders Integrating Government Ministries
Detailed Project Report and Future Outlook	Formulation of the Project, its Objectives & Targets, Cost Benefits & Outcomes, Monitoring mechanisms and Action Plan including technology, cybersecurity and other relevant issues	Justification of the Project Project Objectives & Targets Project Design & Costs Envisaged Benefits & Outcomes Evaluation parameters {Measurable Indicators} Project Monitoring and MIS Roles of various Stakeholders Strategy and micro level action plan clearly defining roles of various stakeholders.

SWOT Analysis in DAPT

A SWOT analysis helps in understanding the strengths and weaknesses and helps in identification of open opportunities and the threat that can come along. It provides with a vision to differentiate between marginal and valuable opportunities. It also helps in deciding what to exploit and what to ignore. SWOT analysis gives a taste of what are the threats and their intensity. It facilitates with options to keep an eye on the unlikely to cause damage and beware of increasingly dangerous threats. Finally provides an opportunity to identify the gaps that will lead to the preparation of a strong and structured Strategic Roadmap for DAPT. Below is the SWOT analysis of DAPT in India.

Strengths

- There is broad and detailed domain know-how as well as process know-how available.
- Many domains have innovative technology and skilled people.
- There are many universities/institutions with high capacity where state of art research being carried out.
- Avenues where good science/engineering /domain specific education can be obtained.

- Immense growth opportunity in DAPT
- Growing start-up base accelerating the growth: Ten-fold increase in start-ups in the last four years.
- Innovative offerings focusing on end-to-end customer business needs.

Weaknesses

- There are no established cooperation networks between academia and industry.
- Computer clusters and cloud resources are readily not available and accessible to the users/stakeholders such as Researchers in the Institutes and Research Labs.
- There are not many SMEs that are dynamic and flexible and can react quickly to technology changes.
- There is no existing and strong technology-driven market in India.
- There is a lack of a solid start-up culture because of risk aversion and fear of failure.
- There are few large companies to lead the market and many small-sized companies that need nurturing.
- There is no visibility of ecosystem service offerings.
- Lack of seamless data access and inter-connectivity, and low levels of interoperability: data is often in silos and data sharing is difficult due to an ineffective Data Sharing Policy as well as standardised e.g. formats and semantics.
- Migration of data between systems, versions or partners is challenging.
- Access and processing of dataset those are too big to be given to the end user.
- There is a lack of specialized education programmes for DAPT.
- There are not enough skilled people to participate in advanced manufacturing fields.
- Rules and regulations are fragmented across the country/industry/domain.

Opportunities

- Being a multicultural society, various cultures/practices/strengths/approaches can result in creative thinking if they are mixed.
- The proposed mission and best practice examples in other initiatives can lead to synergies.
- Strengthening the Indian market, e.g. by fusing the emerging start-up nucleus.

- Create lots of SMEs for the low hanging fruits of DAPT for which agility is required.
- Investment in the entire innovation chain, beyond basic research.
- Investment support mechanisms for SMEs/Research/ Institutions/ Students/ Scholars/ Entrepreneurs.
- Collaboration within Industry/ Academia/ Service Providers.
- Improve and encourage innovation & creativity to create cost-effective solutions.
- There is the opportunity to open up completely new and different business areas and services.
- New applications can be created throughout the DAPT ecosystem, ranging over acquisition, extraction, analysis, visualization and utilization.
- Wearable sensors and sensor technologies become mainstream generating more data. Analytics is an opportunity.
- The explosion of device types opens up access to any data from any device for greater and more varied applications.
- Development of APIs for access becoming standardized and available.
- Interoperability tools and standardized APIs to facilitate exchange.
- Greater visibility and increased use of directory services for technology sources.
- Contextualization and personalization of DAPT.
- The evolution of different sectors and the increased volume of themes enable innovative applications to be developed.
- Use and exploration of DAPT to be ubiquitous in education and training.
- User-generated and crowd-sourced content increasingly available that will help a variety of recurring problems solved once for all.
- Shift from technology push to end-user engagement.
- Create technology driven rich and complex value chains.
- Develop strong and workable policies for technology access in the country across private and public to help build comprehensive capabilities.
- As the presence of the Internet of Things (IoT) — such as connected devices, sensors and smart machines — grows the ability of things to generate new types of real-time information and to actively participate in an industry's value stream will also grow, (GARTNER), it is an opportunity for India. Similar will be the application of DAPT in Smart City Verticals: Smart Energy & Power, Intelligent

Transportation & surveillance, Ubiquitous Healthcare Systems and Intelligent Networks and Communication Systems and DAPT applications on Defence Systems etc. will create a new breed of intelligent ways of operations and management.

Threats

- Many skilled professionals leave the country to work in other regions; adding to the risk of a "Brain Drain".
- Acute lack of skilled professionals and graduates to the requirement of industry.
- Non-standardization of the 'contents', 'duration', 'mode of delivery' and 'certification' of the skilling and or up-skilling efforts made by the education/training ecosystem of the society.
- There are fewer start-up ecosystems in DAPT areas.
- Policies are often too connected to the legacy technologies/processes.
- Complete analysis of ethical and privacy issues is needed.
- Risk of over-regulation and protectionism in the country as compared to elsewhere in the developed world.
- Technology & Techniques: To capture value from DAPT the organizations will have to deploy new technologies e.g. storage, computing and analytical software. The range of technology and technique challenges and priorities set for tackling them will differ depending on the technical maturity of the institution.
- Shortage of Skills: There are a wide range of skills relevant for DAPT, including knowledge of smart sensors and systems, sensors networks, communication networks and computing on the edge, fog and cloud and data analytics on the cloud and the ability to programme and use software, develop and deploy industry-specific knowledge and roll-out DAPT products and solutions. These skills may not be available in required quantity and quality.
- Business-Education Collaboration: One way to provide the multi-disciplinary skills required for DAPT is for students to work closely with a company during their studies. Collaboration between a university/institution with expertise and business with real-world problems can be beneficial for both parties.

2.2 Target Beneficiaries

a) Telecommunications

The very basic nature of DAPT is interdisciplinary and all walks of industry and society are going to be revamped with disruptive technological innovations. It will impart intelligence and decision-making capability to IoT and CPS. Primarily an IoT or CPS system consists of sensors and actuators interfaced with local processing node, called sensor node. In a real physical system, there may be hundreds and hundreds of such nodes, communicating through each other. Sensors Nodes are also interconnected creating a sub network to feed information to Gateway of many Gateways. These gateways are connected on the cloud which is the major centre for large scale data analytics and predictions. The inferences so obtained are then processed further to generate the actuation signals, that are again transmitted back, all across the network and target sensor nodes, so as to dynamically control the characteristics of the real-physical system. DAPT has applications in every part of the IoT and CPS and such applications transform the systems to be Smart IoT and Intelligent CPS. Following are the major applications and beneficiary of the use of Intelligent Networks and Communication Systems;

i. Sensor Node self-analytics and performance check: DAPT is implanted on the sensor node itself to generate unique cross check of the functional characterisation of the sensors and actuators connected. As long as sensor signals pass this self-verification routine, the sensor node is considered healthy and its signals are passed on to the network. In may also be considered as the primary block of the blockchain of the information being transmitted. In case of failure, DAPT also imparts the capability tp a sensor node to operate in fault-tolerant mode and isolates some of the sensors that are not performing satisfactorily. Complete health status of each sensor and sensor node can be accessed and reliability of the system is enhanced.

ii. Real-time communication with Time Sensitive Networks (TSNs): In Industry 4.0 paradigm and with the strict requirements of CPS, the information packets are to be exchanged over the network with guaranteed-delivery protocols and well within the time-delay criteria of less than a milli-second to 1 micro-second delay time. Accordingly, absolutely new hardware and software protocol stacks are to be developed. Current, networking protocols and standards do not apply in these. Accordingly, whole new set of information exchange and processing protocols will be designed to comply with the

industry 4.0 requirements and DAPT will play an important role in information exchange with probabilistic and stochastic models for assured delivery. Almost all the industry protocols and networking models will be revamped and it will generate significant IPRs and disruptive innovations in all types of networking and communication paradigm.

iii. Edge, Fog and Cloud Computing Paradigm: DAPT will significantly boost and disruptively innovate the way data can be gathered, processed and forwarded in intelligent CPS. Using DAPT, the information will be segregated in different levels of information and in the order of priority, information can be forwarded in multiple go, and complying the requirements. At the cloud level, all the information will be processed using wide variety of algorithms and complete process control can be implemented at cloud, network and edge level, making the system performance to be very crisp and predictable.

DAPT applications using Intelligent Networks and Communication Systems: Industry 4.0 compliant network backbone will usher widest ranges of applications such as in Smart City Verticals: Smart Energy & Power, Intelligent Transportation & surveillance, Ubiquitous Healthcare Systems and Intelligent Networks and Communication Systems and DAPT applications on Defence Systems etc. It will create a new breed of intelligent ways of operations and management, in all priority areas of industrial and societal benefits and requirements, both nationally and globally.

b) Power

Smart power generation and distribution is an essential part of smart cities which are the engine of economic growth of every country. The DAPT plan to develop a technology in the development of smart homes and smart cities through smart hybrid grid. In this way, it improves the quality of life and attracts investment to the cities, setting a momentum for growth and development of our country. Moreover, in rural India the distribution grid is usually weak and 24 hrs power supply is still a big challenge. In such areas, solar PV integrated interconnected smart homes may be a prevalent viable solution of the power problem. In general following are some of the target beneficiary sectors of DAPT

i. Energy Management

The DAPT for the energy sector has large-scale impact for both primary energy consumption reduction as well as grid stability problems. In general, the main features that a DAPT must have are 1) Optimum Power Flow 2) Autonomies 3) Close integration

4) Distributive Networking. The research focus areas include improving the sustainability of energy system by better resource utilization and management, modelling of complex interactions between electric grids (physical), and IoT and security of the power system against cyber threats.

ii. Environmental Impact

A class of effective DAPT can be developed that monitors the environmental conditions or the ambient conditions in indoor spaces at remote locations. It gives an environmental friendly smart distribution grid with green house power generation and distribution.

iii. Infrastructure Advancements

The DAPT is helpful in the Infrastructural development of and can be used to analyze data communication between the distributed sensors and actuators of a building. In smart homes, the sensors and actuators are configured such that they can be remotely controlled through the Internet. Through this, the activities of the users can be monitored. Smart community takes the concept of smart homes further by using networking among a group of smart homes. The individual homes are modelled as multifunctional sensors, and whenever necessary, automatic or human-controlled physical feedback is given to improve community safety, healthcare quality, and home security. The information and communication infrastructure of the building as energy consumption and energy/operations optimizers can be developed using DAPT. All public infrastructures are monitored to assess their condition by personnel through scheduled visits, a visual inspection is often not sufficient, as anomalies may still go undetected. A more efficient approach to monitoring is to install a variety of sensors across the structure to monitor its state continuously and determine its upkeep.

c) Defence Research and Development

The defence sector is the major Stakeholders for DAPT. The defence community has made major strides with two phases in the evolution of analytics—descriptive and lower-level diagnostic [Analytics Handbook; © 2019 Booz Allen Hamilton Inc.]. Descriptive analytics are the bread-and-butter of decision-making in defence organizations today. They sort through and summarize raw data to make it understandable, through spreadsheets, charts, reports and other kinds of presentations. Descriptive analytics commonly help defence organizations determine the current situation—levels of

manpower, training, or equipment, for example, or where adversaries are moving personnel, material or financial assets. These analytics are also used to examine past trends, with the aim of guiding future actions. Data science, predictive analytics are:

i. Technologically feasible. New approaches, designed expressly for the age of big data, have overcome the obstacles that have long limited analytics. Defence organizations can now bring together and explore their data in profound new ways.

ii. Practical. Defence organizations have already done much of the groundwork, making the bar of entry to predictive analytics relatively low. And, new tools are making it possible for these organizations to ramp up analytic capabilities quickly, and put them directly in the hands of defence analysts and commanders.

iii. Highly cost effective. Substantially less time and effort are needed for data preparation and analysis, enabling defence organizations to increase their analytic output at lower cost.

In addition, the DAPT may have a very large number of stakeholders having their stakes very divergent fields. The major beneficiaries are given below:

(a) Defence Industry:

The industry and commercial firms associated with the Defence sector will stand to benefit from the analytics and technologies generated in this Mission:

(i) Defence Device & Equipment Manufacturer

(ii) DRDO

(iii) Non-Government Organizations (in field of Defence sectors)

(b) Indian Military and DRDO Labs:

The Indian Military and DRDO Labs directly will be benefited from the analytics and technologies generated in this Mission:

(i) Radar and LIDAR like technologies for Surveillance and Imaging

(ii) Defence Hospitals regarding health-related equipment and sensors

(iii) Power units of defence

(iv) Communication units of defence

(c) Defence Corridor:

The defence corridor project of Uttar Pradesh for indigenous manufacturing and creating skills in defence sector will be another potential beneficiary. IIT (BHU) is one of the knowledge partners in this initiative and has established a dedicated centre

"Malviya Centre of Excellence in the Defence Sector". The proposed CoE of DAPT will support defence corridor further in various sectors like Health, Power, Transport and defence technologies in surveillance and securities etc.

d) Road Transport and Highways

The transportation sector is the most important part of any modern economic infrastructure today with significant impact on energy and environment. DAPT helps to make transportation systems smart, efficient and environment friendly. Traffic flow simulation requires intensive data and processing power which when applied can open up a plethora of opportunities to estimate the effect of various transportation improvements on driver behaviour and experience. Sound DAPT would enable us to understand real-world transportation system dynamics and travel behaviour impact. The transportation system interacts with information and communication technology (ICT), transportation infrastructure, vehicles and drivers, and multimodal transportation systems. Mathematical models of transportation systems and mobility management, incorporating both real and expected scenarios, can be embedded into transportation analysis. The DAPT-based traffic control analyses the information flow amongst computer systems, road infrastructure (such as signals and message signs) and road users in the traffic control system. The DAPT approach in transportation is not only about applying advanced ICT, it is also about building new systems by integrating ICT and physical processes which can be introduced as smart transportation systems. Smart transportation systems aim to achieve crash avoidance in autonomous vehicles as well as real-time traffic management for autonomous urban mobility, an important issue in smart cities. A sound cyber-physical transportation control requires efficient use of materials, energy, algorithms, as well as data to achieve the objectives of mobility and safety. Also, the way data is collected, stored, transmitted, processed and presented, is important for achieving those objectives. Smart transportation systems are envisioned to address the numerous challenges faced by the transportation sector. One category of solutions envisioned in intelligent transportation systems pertains to the real-time, reliable delivery of traffic-related information to drivers. This consists of both safety-critical applications (such as blind spot warnings during lane changing) and applications that improve the driving experience and help the environment (such as notification of congestion and rerouting advice that can help to alleviate traffic congestion and lost productivity). Supporting these applications requires a thorough understanding of the

smart transportation systems problem space about its types of communication networks. Timely and reliable dissemination of information via vehicle-to-vehicle and road-side infrastructure communication is a difficult problem due to multiple challenges. Some challenges are imposed by the physics of the system, including the wireless radio transceiver power, shared nature of the wireless channel, mobility of the vehicles, and density of the vehicles. Other challenges arise from the vagaries of the cyberinfrastructure, including behaviour of protocols like IEEE IEEE 802.11 Media Access Control (MAC), Address Resolution Protocol (ARP), Internet Protocol (IP) addressing and routing, and the Transmission Communication Protocol (TCP). While the smart transportation applications based on DAPT are diverse e.g. Car merging assistants [32], Cyber-Physical traffic control systems, Smart traffic lights for traffic flow control, Traffic delay estimation, Traffic flow dynamics, Vehicle tracking systems, together they form the basis of mobility in a smart city.

e) Health and family welfare:

There would be two broad groups that would be enhanced by the outcomes of the Mission:

i. Recipients of the Mission benefits

Regarding the disease screening, diagnostic, and control aspects, the beneficiaries are:

(i) Patients.
(ii) General unwell populace.
(iii) Disabled people
(iv) Care givers.

Likewise, regarding the preventive aspects, the segments benefitted are:

(i) General population.
(ii) Visual / hearing deficit people.
(iii) At-risk groups
(iv) Special kids
(iv) Ethnically disadvantaged groups.

Further, from the age-wise perspective, the recipients would encompass:

(i) New-borns
(ii) Infants,
(iii) Toddlers
(v) Children
(vi) Adolescents
(vi) Adults,
(vii) Elderlies,
(viii) Senescent people.

The target population that will be helped is indeed the general Indian people at large.

ii. Industry and Service Sector

The industry and commercial firms associated with the Healthcare sector will stand to benefit from the analytics and technologies generated in this Mission:

(a) Medical Device & Equipment Manufacturer

(b) Hospitals

(c) Non-Government Organizations (in field of Health and Social welfare sectors)

iii. Policy Makers, Central / State Governments, W.H.O

Based on the data accessed by the Mission, it will also be able to generate Disease Density Field Maps for different Neurological diseases and Mental Disorders, that will be useful for Central / State Govt. and International policymakers to institute corrective measures. These Field Density maps can be both on Static and Dynamic templates, as follows:

(a) Static Mapping Atlas (Disease Density Field Mapping):

Prevalence Rate of different diseases at a specific time can be obtained and mapping atlas generated. Fig 2.1 shows an illustrative mapping of two different mental disorders (Developmental disability, Conduct disorder) across India at specific time, say 2017 or 2023. The Mission may be able to furnish prevalence mapping of different disorders as Cerebral Stroke, Neonatal asphyxia or Vascular Dementia, at a particular desired time.

(b) Dynamic Mapping Atlas (Disease Density Field Mapping):

*Differential Incidence Rate*of the time-wise progression of a specific disease over a substantial temporal span can also be derived and mapping atlas produced. Accordingly, Fig 2.2 shows virus caused Brain Fever (infective encephalitis) in U.P., across the 20-year time duration. The Mission can provide Differential Incidence mapping of progression of different disorders (as Cerebral Stroke, Neonatal asphyxia, and Vascular Dementia), at yearly, 2 yearly or any suitable time span (month gap, or 6-month gap).

(c) Disease Migration Trajectory Mapping:

The Migration Mapping of Brain fever (virus encephalitis) is shown in Fig. 2.3 representing the shift in the 20-year period. The Trajectory Mapping thus indicates that

new anti-mosquito intervention and pro-sanitation measures is critically needed at the new District B.

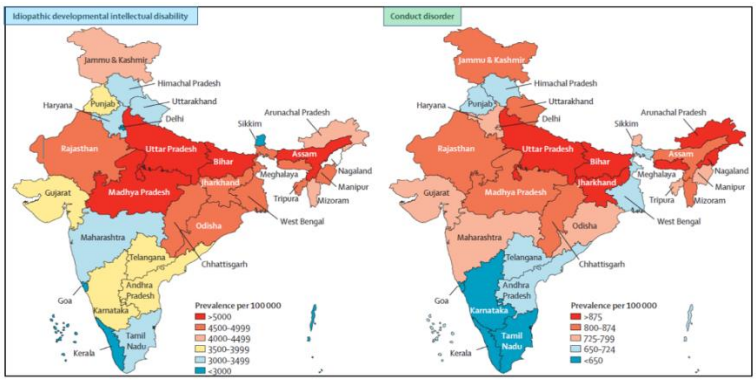
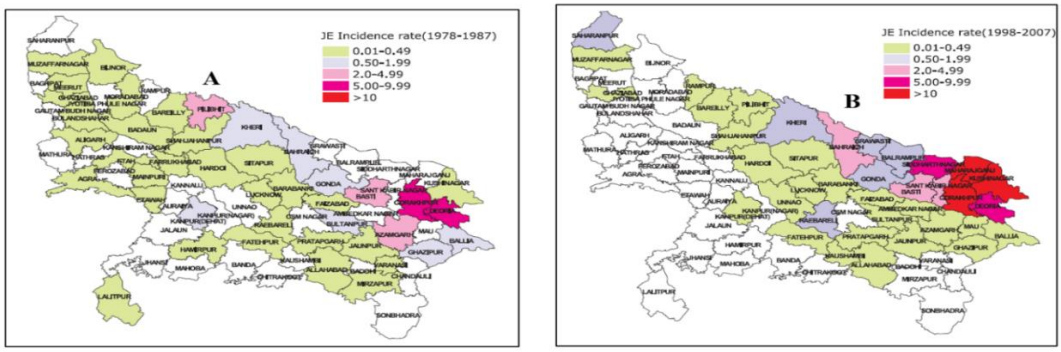


Fig.2.1: *Static Mapping Atlas:* Disease Density Field Mapping of two different disorders (Development disability, and Conduct disorder) at year 2017. (Adopted from LC Disease Mapping Schema).



(a) (b)

Fig.2.2: *Dynamic Mapping Atlas*: Disease Density Field Mapping of Brain fever in U.P. (viral encephalitis) at year 1987 & 2007. (Adopted from NCDC Disease Mapping Schema).

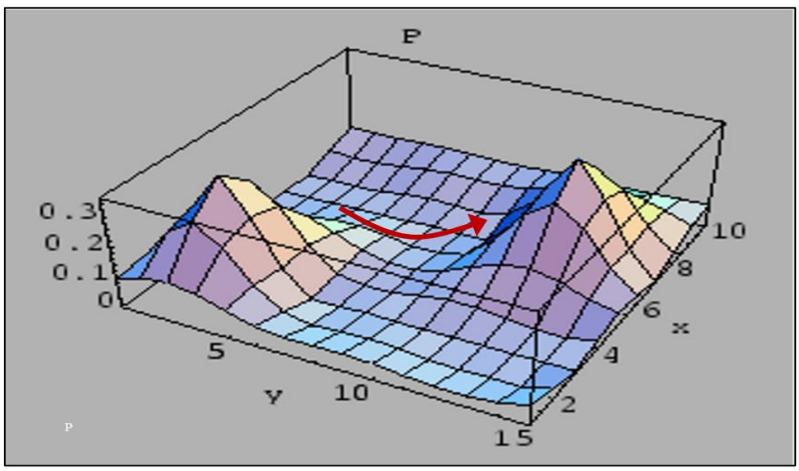


Fig. 2.3:*Disease Migration Trajectory Mapping:* Density Plot of Brain fever (virus encephalitis) showing the higher disease density (red arrow) shifting from District A [fig. 2.2(a)] to District B [fig. 2.2(b)], in U.P.

Benefit Impact on Weaker Sections of the Society

To ensure that the outcome of the program do reach the economically disadvantaged sectors of the society, a 3-pronged tactical approach shall be utilized, consisting of interaction with country-wide health sector at three levels:

- Provincial or state-wise Health System Upgradation Programs of the State governments.
- Ayushman Bharat, for almost half of the country's population (lower income bracket).
- Healthcare Divisions of Municipal Administrations, Urban govts., or State capitals.

Interactive Benefits with the Health ecosystem

Particular emphasis would be given to the possibility of the benefits reaching the broadest spectrum of the community.

For this, we would particularly have partnering or inputs from pertinent organizations, as-

- Ministry of Social Welfare, Ministry of Maternal & Child Welfare,
- NGOs like the Gates Foundation, Infosys Foundation, and Tata Trust,
- New Delhi offices of UNDP, WHO, UNICEF.
- Indian node of SAARC Health Division, and GOI's Indian Ocean Rim Initiative.

2.3 DAPT and National Initiatives

The DAPT programme rightly fits into National initiatives like SDGs, Digital India, Swachh Bharat, Make-in-India, Industry 4.0, SMART Society 5.0, Skill India and Start-Up India as narrated in DPR of DST. The DAPT Programme facilitates and caters to these national initiatives by developing India specific core technologies, human sources development and develops advanced skill sets and will feed into the Innovation and Start-up ecosystem of GoI. The following are some of the national priorities wherein IDPT can play a role in their implementation and success (Taken from DPR of DST as it is relevant here).

(a) INDUSTRY 4.0: The fourth industrial revolution is already on its way. Revolutions are fast, disruptive, destructive and irreversible. India needs to prepare itself for the inevitable change. Industry 4.0 will be a challenge and may also have continued advantage in the global manufacturing industry. The world has already witnessed three industrial revolutions, which could also be described as disruptive leaps in industrial processes resulting in significantly higher productivity. However, while some areas will

see fast and disruptive changes, others will change slowly and steadily at a more "evolutionary" pace. This time, physical objects are being seamlessly integrated into the information network. The real world is turning into a giant information system. Industry 4.0 provides relevant answers to the fourth industrial revolution. It emphasizes the idea of consistent digitization and linking all productive units in an economy. The main characteristic of industry 4.0 shall be:

Interdisciplinary Data Science & Predictive Technologies: Data is often seen as the raw material of the twenty-first century. Indeed, the amount of data available to businesses is expected to double every year. A plant of the future will be producing enormous data that will need to be saved, processed and analyzed. The ways and means employed to carry out this will significantly change. Innovative methods to handle this enormous data and to tap the potential of cloud computing will create new ways to leverage information.

(b) DIGITAL INDIA: The Government has estimated an investment of US$ 26 billion in technology in coming years for digitization, infrastructural improvements, and push for manufacturing and technology in healthcare and agriculture. The Indian government's Digital India programme, which aims to transform India into a digitally-empowered society and knowledge economy, will bring forth a lot of opportunities for a large number of IT industry players to develop platforms providing government services and information to people in all parts of the country. Security and data accessibility solutions will see increased demand for data scientists from the government.

(c) SMART CITIES: The development of 100 smart cities, under the 'Smart Cities' GoI initiative, will require companies to build consortium to bag these projects. This will drive investments at all layers of ICT infrastructure, benefiting companies which are into technology consulting, telecommunications, networks, hardware infrastructure, managed services and systems integration. The designing of 'SMART cities' involves convergence of spatial data, census data, crime data, natural resources, transport, energy, education data etc. to arrive at location-specific city models. Data Science is the core discipline which will enable in arriving solutions.

(d) SKILL INDIA: Govt focus on enhancing the skill sets both at ground level and high-value areas. The efforts facilitate or catalyse initiatives that can potentially have a multiplier effect as opposed to being an actual operator in this space. The approach is to develop partnerships with multiple stakeholders and build on current efforts, rather than undertaking too many initiatives directly, or duplicating efforts currently underway. To

scale up efforts necessary to achieve the objective of skilling / up-skilling 150 million people.

2.4 Sustainable Development Goals (SDG) and DAPT

The relevance of the different DAPT Domains regarding the SDGs is highlighted below.

DAPT at IIT (BHU) goal will be to support immediate thrust/application areas of viz. energy, defence, intelligent networks, health & well-being, and communication systems apart from priority areas of nationally scalable smart city solution models e.g. Swachh Bharat (Clean India) mission, pan India water resource mission, national gas network and alike to start with. The following SDG are proposed matching with the goals as proposed by DST in its DPR.

Table 2.4: Sustainable Goals and DAPT Contributions

S No	Sustainable Development Goals (SDG)	Nodal Ministries/ Departments	NM-DAPT contribution and linkages
1	Data Analytics and Predictive Technology in interdisciplinary areas	Ministry of communication, Health, Transport, Power and Defence	Provide data analytics framework, algorithms, visualisation tools and data fusion methodologies in all the focussed sectors Communication, Energy, Health, Transport and Defence.
2	Ensure healthy lives and promote well-being for all at all ages	Health & Family Welfare	Cyber systems-based health delivery for rural areas, IoT based remote testing, consultancy and monitoring
3	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Human Resources Development	Skill and semi-skilled HR Development, UG/PG/Doctoral/ Post-doc in high-end DAPT technical resources development
4	Ensure access to affordable, reliable, sustainable and modern energy for all	Power	Grid optimization, distribution models, demands forecast, predictive analytics and development of SMART Intelligent Grids.
5	Make cities and human settlements inclusive, safe, resilient and sustainable	Urban Development	Enabling sustainable management of basic resources – energy, water, food, health, sanitation etc for SMART Cities development
6	Strengthen the Defence	Ministry of Defence and Defence corridor Govt. of India	Development of smart surveillance systems, energy solutions, smart sensors, air, water and health monitoring systems.

S No	Sustainable Development Goals (SDG)	Nodal Ministries/ Departments	NM-DAPT contribution and linkages
7	Strengthen the means of implementation and revitalize the global partnership for sustainable development	Finance, Science & Technology, External Affairs, Commerce & Industry, Environment & Climate Change, Statistics &Programme Implementation	Development of International collaborations in DAPT and related areas.
8	Industry 4.0, Society 5.0, Smart Cities Mission, Digital India, Skill India & Stand-up India	Ministry of Health, Power, Communication, Defence and Highways	DAPT based infrastructure development as per the standards.

2.5 The outcomes of the different DAPT Domains are elucidated below:

The following outputs are estimated to come out of DAPT in major five focussed areas:

Table 2.5: Measurable Deliverables: DAPT on Telecommunications

Objectives/ Indicators	Unit name	Measurable Outputs/ Deliverables
To promote and foster R&D in: "Data Analytics & Predictive Technologies in Intelligent Networks and Communication Systems	No. of research projects	60
To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.	No. of technologies	60
To enhance high-end researchers base, Human Resource Development (HRD) in these emerging areas.	No. of students	500
To establish and strengthen the international collaborative research for cross-fertilization of ideas.	No. of collaborations	12
To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	No. of start-ups	30
To set up world-class interdisciplinary collaboration centers of excellence in several academic institutions around the country, with a substantial amount of funding to enable them to achieve significant breakthroughs.	No. of CoEs	1

To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	No. of partnerships developed	5
To set mission mode application goals and foundational themes for excellence for different centers.	No. of Test beds	5
To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system	No. of incubation centers	1
To address some of the National issues and development of sector-specific solutions.	No. of domain-specific solutions	15
No of Research Papers	Number	75
Number of new tools	Number	12
Number of Solutions created for Govt Departments/ Organizations	Number	5
Number of Best Practices	Number	5
Number of UG/PG fellowships	No of fellowships	100
Number of Ph Ds/ Post-Docs	No of fellowships	25
Number of faculty Trainers Trained	No. of trainers	100
Number of implementing agency	Number	5
Expected requests received from Govts etc	Number	10
No of student training programmes	Number	10
Number of entrepreneurship development programmes	Number	10
No of the new areas	No. of areas/ Sectors	5
Number of tie-ups with industry	No. of tie-ups	10
Number of international collaborative research projects	Number	12
No of cluster-based network projects	Number	2
Number of awareness programmes	Number	5

Number of participants benefited through awareness programmes	Number	300
No of national workshops/ conferences	Number	10
Number of collaborative international conferences	Number	5
No. of Infrastructure projects	Number	3
Number of international experts participation	Number	5

Table 2.6: Measurable Deliverables: DAPT on Power

S No	Components	Activities	Minimum Expected Measurable Outputs/ Deliverables
1	Technology Development	Number of Technologies (IP, Licensing, Patents, etc)	5
		Technology Products	5
		Publications, IPR and other intellectual activities	20
2	HRD and Skill Development	High end skill development	40
		Graduate Fellowship	50
		Post Graduate Fellowships	10
		Doctoral Fellowships	5
		Post Doctoral Fellowships	5
		Faculty Fellowships	1
		Chair Professors	1
3	Entrepreneurship and start-ups	Grand Challenges and Competitions	1
		Promotion of young and aspiring entrepreneurs	1
		Entrepreneur in residence	5
		Start ups and spin off companies	3
		Technology Business Incubator	1
		Seed support system	1
		Dedicated Innovation Accelerator	1
4	International Collaborations	International Joint UG/PG degree programs	2
		International travel/ exchange programmes	10
		International workshops/conferences/meetings	2

Table 2.7: Measurable Deliverables: DAPT on Defence Research and Development

Objectives/ Indicators	Unit name	Measurable Outputs/ Deliverables
To promote and foster R&D in: "Data Analytics & Predictive Technologies in Defence"	No. of research projects	50
To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.	No. of technologies	50
To enhance high-end researchers base, Human Resource Development (HRD) in these emerging areas.	No. of students	300
To establish and strengthen the international collaborative research for cross-fertilization of ideas.	No. of collaborations	10
To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	No. of start-ups	25
To set up world-class interdisciplinary collaboration centers of excellence in several academic institutions around the country, with a substantial amount of funding to enable them to achieve significant breakthroughs.	No. of CoEs	1
To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	No. of partnerships developed	3
To set mission mode application goals and foundational themes for excellence for different centers.	No. of Test beds	3
To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system	No. of incubation centers	1
To address some of the National issues and development of sector-specific solutions.	No. of domain-specific solutions	5
No of Research Papers	Number	50
Number of new tools	Number	5
Number of Solutions created for Govt Departments/ Organizations	Number	2
Number of Best Practices	Number	5
Number of UG/PG fellowships	No of fellowships	100
Number of Ph Ds/ Post-Docs	No of fellowships	25
Number of faculty Trainers Trained	No. of trainers	20
Number of implementing agency	Number	3
Expected requests received from Govts etc	Number	2

No of student training programmes	Number	5
Number of entrepreneurship development programmes	Number	5
No of the new areas	No. of areas/ Sectors	3
Number of tie-ups with industry	No. of tie-ups	5
Number of international collaborative research projects	Number	10
No of cluster-based network projects	Number	1
Number of awareness programmes	Number	5
Number of participants benefited through awareness programmes	Number	100
No of national workshops/ conferences	Number	5
Number of collaborative international conferences	Number	2
No. of Infrastructure projects	Number	1
Number of international experts participation	Number	5

Table 2.8: Measurable Deliverables: DAPT on Road Transport and Highways

Objectives/ Indicators	**Unit name**	**Measurable Outputs/ Deliverables**
To promote and foster R&D in: "Data Analytics & Predictive Technologies in Health and Family Welfare	No. of research projects	20
To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.	No. of technologies	15
To enhance high-end researchers base, Human Resource Development (HRD) in these emerging areas.	No. of students	300
To establish and strengthen the international collaborative research for cross-fertilization of ideas.	No. of collaborations	10
To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	No. of start-ups	20
To set up world-class interdisciplinary collaboration centers of excellence in several academic institutions around the country, with a	No. of CoEs	1

substantial amount of funding to enable them to achieve significant breakthroughs.		
To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	No. of partnerships developed	5
To set mission mode application goals and foundational themes for excellence for different centers.	No. of Test beds	2
To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system	No. of incubation centers	1
To address some of the National issues and development of sector-specific solutions.	No. of domain-specific solutions	5
No of Research Papers	Number	40
Number of new tools	Number	15
Number of Solutions created for Govt Departments/ Organizations	Number	5
Number of Best Practices	Number	5
Number of UG/PG fellowships	No of fellowships	100
Number of Ph Ds/ Post-Docs	No of fellowships	15
Number of faculty Trainers Trained	No. of trainers	50
Number of implementing agency	Number	5
Expected requests received from Govts etc	Number	5
No of student training programmes	Number	5
Number of entrepreneurship development programmes	Number	3
No of the new areas	No. of areas/ Sectors	2
Number of tie-ups with industry	No. of tie-ups	5
Number of international collaborative research projects	Number	3
No of cluster-based network projects	Number	~~2~~

Number of awareness programmes	Number	5
Number of participants benefited through awareness programmes	Number	150
No of national workshops/ conferences	Number	5
Number of collaborative international conferences	Number	2
No. of Infrastructure projects	Number	2
Number of international experts participation	Number	10

Table 2.9: Measurable Deliverables DAPT on Health and Family Welfare

Objectives/ Indicators	Unit name	Measurable Outputs/ Deliverables
To promote and foster R&D in: "Data Analytics & Predictive Technologies in Health and Family Welfare	No. of research projects	30
To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities.	No. of technologies	20
To enhance high-end researchers base, Human Resource Development (HRD) in these emerging areas.	No. of students	300
To establish and strengthen the international collaborative research for cross-fertilization of ideas.	No. of collaborations	5
To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	No. of start-ups	20
To set up world-class interdisciplinary collaboration centers of excellence in several academic institutions around the country, with a substantial amount of funding to enable them to achieve significant breakthroughs.	No. of CoEs	1
To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	No. of partnerships developed	3

To set mission mode application goals and foundational themes for excellence for different centres.	No. of Test beds	1
To tie up with incubation centres and accelerators to foster close collaboration with entrepreneurship eco-system	No. of incubation centres	1
To address some of the National issues and development of sector-specific solutions.	No. of domain-specific solutions	6
No of Research Papers	Number	30
Number of new tools	Number	5
Number of Solutions created for Govt Departments/ Organizations	Number	3
Number of Best Practices	Number	8
Number of UG/PG fellowships	No of fellowships	100
Number of Ph Ds/ Post-Docs	No of fellowships	30
Number of faculty Trainers Trained	No. of trainers	20
Number of implementing agency	Number	3
Expected requests received from Govts etc	Number	2
No of student training programmes	Number	3
Number of entrepreneurship development programmes	Number	3
No of the new areas	No. of areas/ Sectors	3
Number of tie-ups with industry	No. of tie-ups	4
Number of international collaborative research projects	Number	2
No of cluster-based network projects	Number	2
Number of awareness programmes	Number	2
Number of participants benefited through awareness programmes	Number	60
No of national workshops/ conferences	Number	3

Number of collaborative international conferences	Number	2
No. of Infrastructure projects	Number	1
Number of international experts participation	Number	5

Apart from the deliverables mentioned in the Tables 2.5 to 2.9, a master's level program such as M. Tech. in DAPT and skill enhancement/development program for serving engineers/engineering practitioners will also be started at IIT (BHU). These programs will help in technology development, skill/HRD training and self-sustainability of the NM-DAPT at IIT (BHU).

Chapter-3

DAPT Technologies and Mission Strategy

3.1 Technology

DAPT is an emerging approach which is implemented by using fusion of various technologies from across disciplines. Some of them are matured and some under development. Technology choices are wide and based on application domain; a set of technologies will be converged to deliver a DAPT. The following are some of the generic technologies that will play a crucial role in DAPT.

3.1.1 System Design

DAPT represents the integration of physical and embedded systems. In describing DAPT, the characteristics help to clarify what type of system is considered, also with regard to different stakeholders and viewpoints. The classification of the DAPTis shown below.

1. Energy Efficient System Design
2. Sensing
3. Adaptive and Predictive Control
4. Optimization
5. Data Fusion Analysis and Processing
6. System Integration

1. Energy Efficient System Design

Energy efficient system design is one of the basic taxonomies of DAPT that involves computations, networking, and physical processes. DAPT design will integrate the best practices of all the multidimensional and application systems like power processor with embedded systems, sensor, control and actuation. The energy efficient system design optimizes the performance of the system. A system design methodology is often iterative process between analyzing the behaviour, structure, and geometry of the system. The development steps for DAPT are requirements specification, design, and implementation. Following are the steps for efficient design:

A. Specification

Specifications of a DAPT design need to capture the power, control, computing, and communication requirements. Specification of DAPT should not only exhibit the its expected behaviour, but it should also exclude undesired or unsafe behaviours. Specifications of a system can also be captured mathematically and are known as a

formal specification. Further, specifications can also be provided graphically which exploits the diversity and power of existing formal specification languages.

B. Scalability

The challenge is to provide design methodologies and tools that scale to large designs, facilitate analysis, and promote understanding of complex systems.

C. Platform design

A platform is the implemented in software and also in software for realizing a system. Platform specifications may again come from the physical domain of DAPT or its application area. As of now, most of the platforms available for DAPT are application specific. Components can be designed to operate with a model, and when deployed, will operate in predictable ways with the deployed system. The rigorous foundations of the models provide a foundation for integration across design domains, design adaptation and evolution, and analysis and verification. Many of the techniques developed have been deployed in a wide range of domain-specific applications, including hardware and field-programmable gate array (FPGA) synthesis, signal processing, automotive system design, computer architecture design and evaluation, instrumentation, wireless system design, network simulation and design. Platform design can be classified further as Hardware and Software.

C.1 Hardware

Physical components of a DAPT decide the hardware platform. Its efficiency can be judged by operations per time unit. It will include the interface circuits, controller, sensors, smart devices, and actuators. The controller or computational part is usually called a node and has processor. A variety of platform nodes are available to be considered for DAPT system design ranging from small scale to large scale. Companies are coming up with new architectures & devices to cater the need of future DAPT in their domain. Nvidia boasts of Jetson TX series as power efficient and computationally competitive. Intel too has come up with power efficient & portable single board computers. Arduino and Raspberry are well-known community platforms, and there exist many more. All of these platforms play a significant role in development today.

C.2 Software

The programming aspects of a DAPT are called a Software platform. It will include the functions, programmes and other GUI components. The main objective of efficient software design is to extract the maximum possible synergistic output from hardware components and system. Simulink & eclipse are preferred platforms for simulation and integrated development environment. DAPT also can be a System-of-systems as in Smart Grids and Smart Cities. It presents the architectural foundations of a cloud-centric framework for automating the development and deployment common open service platform for DAPT applications.

2. Sensing

Physical entities of DAPT are performed by the sensing devices and systems. The sensors and actuators play a bridge role between the physical and cyber world. Different types of sensors (wired and wireless) and actuators are used for richer measurement and control of physical processes. The sensing entities are responsible for collecting important sensor's data and these data are fed to the processing and communication system for further use. Sensing is the key concern for several applications like HealthCare, the elements from Sensing perspective depend upon the localization (positioning in space) of sensors, time synchronization, sensor networks and sensor nodes etc. For example, sensing is the heart of smart infrastructure to collect information from the sensors and monitor public infrastructures, such as bridges, roads and buildings, provides awareness.

3. Adaptive and Predictive control

DAPT systems are typically closed-loop systems, where sensors make measurements of physical processes, the measurements are processed in the cyber subsystems, which then drive processors that affect the physical processes. The control strategies implemented in the cyber subsystems need to be adaptive (responding to changing conditions) and predictive (anticipating changes in the physical processes). This is achieved through a self-adaptation software framework intended for autonomous trains and built on a demonstrator. Model predictive control (MPC) has been used in many industrial applications because of its ability to produce optimal performance while accommodating constraints. However, its application on plants with fast time constants is difficult because of its computationally expensive algorithm. A parallelized MPC that makes use of the structure of the computations and the matrices in the MPC. It has been shown that the computational time of MPC with prediction horizon N can be reduced to O(log(N))

using parallel computing, which is significantly less than that with other available algorithms with similar accuracy, thus providing a Parallelized Model Predictive Control for Distributed Networked Systems.

4. Optimization

Computation optimization is an important paradigm with real-time applications of DAPT. Optimization techniques such as SWARM are used for design architectures, mathematical modelling, computer simulation and computation-intensive numerical optimization. Highly efficient optimization methodologies in design, algorithms and large computational resources requires modern and high- speed computers. The computational design optimization can be defined by the transforming an application's design problem into a mathematical optimization, features of the systems to optimization process and expressing the modifications as functions of the optimization variables and prediction the optimized values. The computational optimization is used to determine the fine-tune features and conceptual layout of the system. Optimization is challenging task in terms of high computational cost of evaluating objectives, nonlinearity, multimodality, discontinuity, uncertainty and problem-solving time of the problem functions in the real-world systems.

5. Data Fusion, Analysis and Processing

The Key issue for DAPT is the collection and acquisition of data such as parallel data collection (via sensors), data fusion, processing of physical data from the environment, locally, globally and in real time. Data from sensors combined with data fusion, data mining, and interpretation enable physical awareness of systems. The integration of Data presents several challenges and opportunities. Data integration for DAPT is not suitable for conventional solutions based on the offline or batch processing. The interconnection with the real-world, in industrial and critical environments, requires reaction in real-time. Therefore, real-time will be a vertical requirement from communication to Big Data analytics. Big Data on the one hand, real-time streams processing for real-time control, and on the other hand, batch processing for modelling and behaviours learning. This system consists of a data collection layer with a unified standard, a data management layer for distributed storage and parallel computing, and a data-oriented service layer.

6. System Integration

DAPT is diminishing the domain boundaries and thus making system integration an obvious challenge for component interactions. Objective is to achieve a stable DAPT enabled CPS. It requires extensive research in interfaces and tool support. These challenges are both at Hardware & Software level. A modular approach may help in defining stable interfaces to interconnect the components whereas a layered architecture is good for achieving protocol simplicity. It is also argued that systematic development of a science for integrating DAPTs is based on investigating compositionality in heterogeneous systems. Authors have attempted to identify the challenges associated with DAPT Integration. The paper suggests the research directions to solve these challenges by extending the passivity-based approach from continuous dynamics to discrete event system models. Other challenges include stability and preserving compositionality in other properties, such as safety, and performance requirements are also an important and essential design goal. Tool support for integration of DAPT should be researched as well. Integration of DAPT is considered as a major challenge. This is largely because of either the theoretical understanding about the physical object is missing or because the integration is usually the last phase of a system development. So, incorporating the modifications to support integration in the last phase becomes almost impossible.

3.1.2 Communication

Communication networks are an essential part of any DAPT as they interconnect the DAPT subsystems and components. The taxonomy classification of communication for DAPT is as follows:

1. Interoperability

DAPT ecosystem requires interoperability to create the “seamless” programmability of the various physical components that enables the full potential of a connected experience. This means DAPT physical components require standards to enable horizontal platforms that are communicable, operable, and programmable across devices, regardless of make, model, manufacturer, or industry. Standardized abstractions and architectures are urgently needed to fully support integration and interoperability and spur similar innovations in DAPT. A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols and virtual ’Things’ have identities, physical attributes, and virtual personalities and use intelligent

interfaces, and are seamlessly integrated into the information network. For a spatially distributed remote nodes setup (e.g. robotic control, industrial automation), wherein the processing capacities are low and power is a premium, the 6LowPAN is the preferred approach. These nodes, which are all homogeneous, will talk through a gateway, which in turns opens up these devices for accessibility from external world. In the DAPT scenario, the physical components such as sensors, control system are all digital things connected to the web. They are monitored and controlled through service frameworks and various applications — custom as well as generic. Thus, there is a strong need for standardization, that enables the semantics being conveyed and understood, and also for interoperability of devices from multiple vendors. The researchers in past have studied the state-of-the-art interoperability issues and challenges and proposed the semantic interoperability standard.

2. Efficient Connectivity

The heterogeneity in DAPT exposes several problems that cannot be easily solved through current control, communications, and software theory. As an example, today's network research often deals with coverage and connectivity issues assuming homogeneous network components. However, coverage and connectivity should clearly be redefined in Cyber-Physical control network systems. Such systems will consist of wired and wireless networks with different capacities and reliability. In particular, a generic framework for the design of DAPT architecture can be developed that has heterogeneous communication capabilities of each component, and real-time guarantees. The researchers have proposed sleep-awake protocol to reduce energy demand of communication through dynamically switching radio between the sleeping mode and active mode. Considering a radio component as main source of energy depletion, the energy-preserving medium access control protocols become popular approaches. As the industrial DAPT involves thousands of connected sensors communicating through the wireless network, the power consumption of sensors is a big concern and limitation for the widespread of IoT. Saving energy should become a critical design goal for IoT devices, such as wireless sensors. There is a need to develop energy-efficient techniques or approaches that can reduce the consumed power by sensors. The online pattern clearly costs a great extra amount of energy for broadcasting temporal solutions. In order to save energy, the concept of self-triggered control is adopted in this paper, in which the controller dynamically determines the next tasks execution time including sampling,

command broadcasting, and changing of action. A joint optimization framework is presented, which combines the objective of control as well as other relevant system objectives and constraints such as communication errors, delays and the limited capabilities (e.g. energy capacities) of devices. The problem is solved by an online optimization approach, which consists of a communication protocol and a simulated annealing-based control algorithm. Meanwhile, by taking into account the communication cost, the author has optimized the control intervals by integrating two kinds of acceptance, i.e., cyber and physical acceptances, into the control algorithm.

3. Location-based Services (LBS)

A location-based service is a software-level service that uses location data to control features. As such location-based services is an information service and has a number of uses in social networking today as information, in entertainment or security, which is accessible with mobile devices through the mobile network and which uses information on the geographical position of the mobile device. Location is the most obvious context attribute, but not the only one- also identity, status or activity, and time characterizes a situation. An integrated system based on Wireless Sensor Networks for patient monitoring, localization and tracking has been proposed in the system can be rapidly deployed in any indoor environment, due to adopted self-calibration method. They developed both a distributed solution entirely running on a low-cost mobile sensor node and a centralized solution that minimize the target node energy consumption. A similar analysis is carried out in, together with a prototype of MEDiSN, a WSN-based system capable of monitoring vital signs of unattended patients. However, patients' localization is only presented as broadly useful, according to the indications of many staff members, depicting this topic as a future feature that can be added as soon as researchers will be able to provide efficient and effective ways to perform it. In the author has presented the indoor location-based smart factory (iLSF) platform, a service model for collaboration among factory workers, facilities, manufacturing materials, and factory control system. The iLSF collects the information from the factory through a protocol that supports self-collaboration among wearable devices, tags of machines, and anchor nodes. The proposed platform enables a worker to automatically configure a machine with their personally preferred value, and receives the working history from a machine. Finally, we suggest various specific service scenarios such as a safety notification to workers in a

dangerous environment and a guide to workers informing them of the proper manufacturing process.

4. Wireless Communication Bandwidth

In DAPT, the major communication happens through wireless medium. The wireless communication bandwidth plays a crucial role while using wireless media. Many efforts have been put by researcher to effectively utilize the wireless bandwidth for DAPT application. A joint power and bandwidth allocation with QoS support algorithm is proposed using convex optimization method is proposed in the algorithm achieves the goal of the total system capacity maximization, while efficiently satisfying the minimum rate constraint of delay-constraint service traffic and proportional fairness of best-effort service traffic. In the author has proposed a new framework, which is called dynamic QoS-based bandwidth allocation (DQBA), to support heterogeneous traffic with different QoS requirements in WiMAX networks. The design of DAPT with wireless control systems must deal with interdependencies between control and communication. For example, while it is well known in digital control that a low sampling rate usually degrades control performance, a high sampling rate may increase resource contention in bandwidth-constrained WSANs leading to long communication delays, which again may lead to degraded control performance. The coupling between wireless communication and control therefore motivates a Cyber-Physical code-sign approach that integrates wireless networks and control designs.

5. Data Transmission

In DAPT, the connectivity among various physical components emphasize the perception of information and provides data support for a variety of specific application through data collection, processing, integration and routing. IoT interconnects Internet information sensing devices like wireless sensor and radio frequency identification (RFID) through wireless network and Internet technology, and it is a new type of network to realize the overall perception, reliable transmission and intelligent processing of information. The research direction is required to realize rapid exchange of data transmission by optimizing existing routing algorithms. In particular, the change of existing network system structure with the “best effort” is needed provide real-time network transmission services for the system. As a burgeoning technique for signal processing, compressed sensing (CS) is being increasingly applied to data transmission

in wireless communications. In the author has investigated the application of CS to data collection in wireless sensor networks, and aimed at minimizing the network energy consumption through joint routing and compressed aggregation. The authors have been investigated how CS can provide new insights into data sampling and acquisition in wireless sensor networks and IoT. In this research, the author briefly introduces the CS theory with respect to the sampling and transmission coordination during the network lifetime through providing a compressed sampling process with low computation costs. The network and data transmission architecture for the long-range sensor networks has been proposed. The proposed network architecture is based on oneM2M IoT standard. It has Infrastructure Node (IN), Middle Node (MN) and Application Service Node (ASN) as network elements. In this method, IN employs cloned MNs to reduce the traffic load at the MN, which is the gateway. ASN delivers data through MN or cloned MNs to the IN. Through the load balancing by the proposed method at the MN, the efficient data transmission for IoT services in long-range sensor networks can be provided.

6. Protocols for Energy Efficient Design:

In modern DAPT, new dimensions of freedom are enabled to energy efficient solutions. adopt a control and optimization approach for energy efficient design in DAPT. Energy is most important factor for designing communication protocols for DAPT. The WSN protocols are widely used for communication between the various physical components must be an energy efficient protocol. The research work in view of the challenges in the design of the energy-efficient Medium Access Control (MAC) protocols for the WSNs. Moreover, it describes few MAC protocols (12 in total) for the WSNs emphasizing their strengths and weaknesses, wherever possible. There are a few attempts to propose and discuss models for energy efficiency WSNs. Most of them are based on the sensor node power consumption model. In particular, it is shown a realistic power consumption model for WSN devices by incorporating the characteristics of a typical low power transceiver. This work proves that for typical hardware configurations and radio frequency environments, whenever single hop routing is possible it should be preferred as it is more power efficient than multi-hop routing. On the other hand, it is shown that an energy model divided into a set of finite state machines that represent the states and transitions of a sensor node's hardware. In addition, in general energy consumption model of WSNs devices based on the actual hardware architecture is proposed. In order to achieve this,

the authors utilize the measured energy consumption performance of the actual hardware components and implement a realistic CSESM (Communication Subsystem Energy Consumption Model) of WSNs devices.

7. Fault tolerance:

In DAPT, the requirement of safety-critical real-time applications relies on basic fault-tolerant communication protocols. The communication backbone of such a system has to be equally reliable and must work fail-operationally that is, it must stay operational even in the presence of faults as long as they meet a predefined fault-hypothesis. A fault-tolerant communication controller is a typical example of an embedded, fault-tolerant system. It is proposed an efficient fault-tolerant and energy-efficient clustering protocol for an IoT system. The performance of the proposed protocol was tested by means of a simulation and compared against the low energy adaptive clustering hierarchy and dynamic static clustering protocols. The results showed that the fault-tolerant and energy-efficient clustering protocol has better performance than both the low energy adaptive clustering hierarchy and dynamic static clustering protocols in terms of energy efficiency and reliability. Similar work has been proposed. In this, the author introduces a fault tolerant, energy efficient and secure clustering scheme for M2M (FESM) area networks that minimise the number of cluster heads (CHs) and active nodes to reduce network energy consumption. The machine type communication gateway and CHs transmit beacon messages to discover the failure of CHs and member nodes, respectively. In literature the author has developed the fault tolerance mechanism for IoT, which is distributed and takes into account the dynamics within IoT. Strip is introduced to store a list of duplicated services, and, each service peer maintains a consistent view of duplicated services in the strip. In combination with the heartbeat protocol, recovery from failure can be achieved by manipulating strips in a distributed manner.

8. Feedback systems

a. Human-in-Loop

Many DAPT include humans as an integral component. Humans are very difficult to model, so understanding and validating such systems becomes particularly challenging. Works that have been done in this field are as follows. In literature, a class of intelligent DAPT, a form of next-generation networked systems that involve humans (particularly, human perception) in the control loop. Here intelligent lighting has been taken as a

representative case to explore the issues that conventional machine learning faces in human-centric DAPTs. This can help in addressing the general problem of how to handle DAPTs characterized by non-deterministic, multiple-output problems. Here an intelligent lighting system that can learn the users' preferences to provide a suitable light condition for a given observed context has been taken. Literature provides a Human-in-the-Loop Cyber-Physical Production Systems Control (HilCP2sC) concept, which can be largely conceived as a natural evolution of distributed manufacturing control paradigms which exploits recent technological progresses in embedded systems, ICT and networking and communication infrastructure, and where Human-System interactive dimension of DAPT plays a significant role as an enabler for intelligent decisional framework bringing human into the cybernetic loop of the manufacturing control system. The reported research concerns an on-going effort toward the introduction and the development of this concept.

b. Economics-in-Loop

Modern DAPT is given expanded scope and greater flexibility by including dynamic pricing signals, financial information, and economic attributes as integral feedback components. The integration of such dynamic value-based parameters provides a wealth of new computationally intelligent behaviour dynamics and dimensions of control that enriches the cyber-physical eco-system. Work done in this field is as follows. With regard to smart buildings (which can be considered as a DAPT) parameters such as Weather data, time-of-use energy prices, and energy load forecasts could be used to better tune its control systems increasing energy efficiency and reducing operating costs thereby considering economics in loop. [56] quantify energy use due to lighting, ventilation, and office equipment in a modern mixed-use office building and explore opportunities for energy conservation and renewable energy production.

3.1.3 Security

The integration of computation, communication, and control units has led to the birth and rapid development of a new generation of engineering systems. These are DAPT which have been increasingly used in fields ranging from aerospace, automobile, industrial process control, to energy, healthcare, manufacturing and transportation, where secure operation is one of the key concerns. By exploiting the sensing, networking, control and computation capabilities, the new generation DAPT is able to connect the cyberspace and the physical space. However, such connections have also provided an attacker the

rich opportunities to perform potential malicious attacks. Security of DAPT is becoming a significant area of research drawing enormous attention in the control, computation, sensing and communication communities. The sophisticated attackers can design strategies specifically to exploit vulnerabilities of the DAPT resulting in system abnormalities that are far from random. The taxonomy classification of DAPT security is as follows:

3.1.4 Privacy

1. Threat Modelling for DAPT

The attack models derived from the attacker model are used to generate parameterized attack procedures and functions that target a specific DAPT. The models have been used extensively in understanding the impact of cyber-attacks on any DAPT and in the design and assessment of detection mechanisms. The Modelling of DAPT under threat models both physical and cyber-attacks and unifies a number of existing attack models into a common framework useful for researchers in the experimental assessment of attack detection techniques. A good amount of the security work on DAPT centres on attack detection. An approach to detect attacks monitors inputs based on a model of the system and tries to find anomalies. The papers apply system modelling to detect attacks by detecting behaviour anomalies; the author defines a framework where the way to conduct specific attacks can be described in relation to the system architecture. In literature, the author analyses the effects of attacks with Markov models. In literature, the author model threats using data flow graphs related to hardware units, while we use patterns and relate threats to architectural units, which we believe are more precise. In literature, they introduce a language (using UML and BNF) to describe DAPT attacks. The model emphasizes the mechanics of the attacks and does not consider the attacker goals. There is no relative timing representation for the attack either. Literature uses a reference architecture to trace propagation of attacks. Another interesting approach to threat modelling uses aspects. Aspects model crosscutting functionality and improve reusability; we think that patterns are more powerful to describe attacks than these models. Stuxnet has been modelled using Boolean Logic Driven Markov Processes (BDMP), a combination of attack trees and Markov processes. Other attack models include attack trees, where the root node denotes the goal of an attacker and a path from leaf nodes to the root node denotes an attack instance, i.e., the steps for completing the

attack. A model using graph theory to express control system failures and attacks is also presented in literature. In literature, a language for modelling multi step attack scenarios on process control systems is proposed, enabling correlation engines to use the models to recognize attack scenarios.

2. Authentication, Key Management, and Access Control

The task of providing security services for the DAPT heavily depends on authentication, authorization and message integrity of DAPT devices and systems. In addition to encryption and authentication procedures, key management processes are also part of cryptographic methods. In particular, computing and communication process for the DAPT, it is necessary to ensure that the data, transactions, communications are genuine. It is also important for authenticity to validate that both parties involved are who they claim they are given in recent literatures. Authentication schemes can offer strong protection against attacks targeting data integrity, but cannot by themselves provide all the necessary security in an operational environment especially under the circumstance of DoS attacks. Hence, authentication schemes are required to detect malicious attacks, collaborate with attack detection and response systems, and even designed to be robust to DoS attacks in the Smart Grid applications. The fundamental requirement for authentication design is to provide efficient multicast authentication schemes for the Smart Grid applications. Therefore, few recent works are directed toward this objective, i.e. fast multicast authentication protocols for power control systems. The most straightforward multicast authentication scheme is to use public key-based authentication. For example, Public Key Infrastructure (PKI) can contribute towards establishing trust between different identities using digital signatures. The access control for DAPT depends on the Trustworthiness of entities play an important role in DAPT security. NIST (National Institute of Standards and Technology) has published the guidelines for smart grid cybersecurity that includes the description of cryptography and key management issues. Informatively, NIST recommends the usage of standard symmetric ciphers such as AES (Advanced Encryption Standard) for message encryption and CMAC (Cipher-based Message Authentication Code) for message integrity on which most security schemes including REMP rely today. It relies on an external key management protocol, ZRTP, to establish one master key for deriving session keys. Moreover, it needs additional time-synchronization for key derivation. We notice that the

per-group key management property of conventional group security schemes is well-aligned with the Publish-Subscribe (hereafter caller pub-sub) communication property as the first property of the DAPT communications.

3. Vulnerability Analysis of DAPT

The prevalence and vulnerabilities of DAPT draw the attention of both researchers and attackers. As the interaction between the physical and cyber systems increases, the physical systems become increasingly more susceptible to the security vulnerabilities in the cyber system. Hence, the vulnerability assessment is a requirement of cybersecurity standards for any DAPT. In literature, the author presents CPINDEX, a security-oriented stochastic risk management technique that calculates Cyber-Physical security indices to measure the security level of the underlying Cyber-Physical setting. CPINDEX installs appropriate cyber-side instrumentation probes on individual host systems to dynamically capture and profile low-level system activities such as inter-process communications among operating system assets. Probabilistic Risk Assessment provides a foundation for the calculation of risk reduction when applied to SCADA security. In literature, the author described a new risk modelling tool, augmented vulnerability trees, and two new indices for quantifying the risk. OCTAVE (Operationally Critical Threat, Asset, and Vulnerability Evaluation), is a framework for identifying and managing information security risks developed at Carnegie Mellon University's CERT Coordination Centre. It is a self-directed activity by a team that draws on the knowledge of many employees to define the current state of security, identify risks to critical assets, and set a security strategy. It also uses event/fault tree analyses to model threats to critical assets.

4. Secure and Trustworthy design of DAPT

DAPT is in most cases safety- and mission-critical. Standard design techniques used for securing embedded systems are not suitable for DAPT due to the restricted computation and communication standards. Integrity refers to the trustworthiness of data or resources. A lack of integrity results in deception: when an authorized party receives false data and believes it to be true. Integrity in DAPT can therefore be viewed as the ability to maintain the operational goals by preventing, detecting, or surviving deception attacks in the information sent and received by the sensors, the controllers, and the actuators. The sensitivity of sensed data and the presence of actuation components further increase the security requirements of DAPT. To address these issues, it is necessary to provide new

design methods in which security is considered from the beginning of the whole design and addressed in a holistic way. In addition, the DAPT is a cross-layer design - starting from models of physical systems, to software, to architecture, and finally to reliability of circuits and devices. Thus, the requirement of certified and trustworthy DAPT design is must for which end-to-end guarantees may be offered.

5. Intrusion Detection System

DAPT intrusion detection addresses the embedded physical components and physical environment in a DAPT, which under attacks, manifest physical properties and normally require a closed control loop to react to physical manifestation of attacks. A reckless adversary can enter the network and immediately disrupt the concerned processes to cause a catastrophe. On the other hand, a more sophisticated adversary may take care to not disrupt normal system operation in order to propagate and set up a distributed attack launched at one point in time. This is the brand of attack that Stuxnet. For this reason, speed of detection (detection latency) is the key challenge in DAPT Intrusion Detection System (IDS) design. The IDS can be of three types. i) Misuse/signature-based intrusion detection is based on a process that compares the signatures with observed events to identify possible incidents, where each signature is a pattern that corresponds to a known threat. ii) Anomaly-based intrusion detection is defined as the process that compares normal behaviours' definitions with observed events in order to identify significant deviations. iii) A stateful protocol analysis is the process that compares predetermined genuine activities of each protocol state with the observed events to identify deviations. Knowledge-based intrusion detection approaches look for runtime features that match a specific pattern of misbehaviour. Some sources refer to this approach as pattern-based detection, Behaviour-based intrusion detection approaches look for runtime features that are out of the ordinary. The key advantage of behaviour-based approaches is they do not look for something specific. This eliminates the need to fully specify all known attack vectors and keep this attack dictionary current. Literature shows studied an IDS for smart utility (water) applications that uses a three-stage back propagation artificial neural network based on Modbus features. Literature shows a behaviour-based IDS for a medical DAPT. The authors propose a distributed design where mobile devices collect data that they forward to a centralized audit server. The study of semi-supervised IDS for smart utility (power) applications called Intrusion Detection System using Neural

Network–based Modelling (IDS-NNM) is presented in [108]. IDS-NNM uses error-back propagation and Levenberg-Marquardt approaches with window-based feature extraction. In literatureauthors propose a multi-trust IDS called Multi-Agent System (MAS) for SCADA applications. Their analysis function, Ant Colony Clustering Model (ACCM), is biologically inspired by its namesake—the ant colony. Multi trust is unexplored in DAPT IDS research. This is the concept of using hearsay/reported information (data from witnesses or third parties).

6. Resilient/Self-Healing System

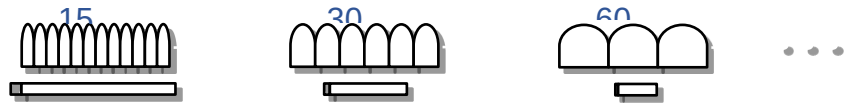
The malicious entities could take charge of DAPT control by exploiting cyber insecurities or physical faults, or their combination. Therefore, to improve DAPT resilience, we need diagnostic tools and automatic control algorithms that ensure survivability in the presence of both security attacks and random faults and include models of the incentives of human decision makers in the design process. The resilient system framework will enable designers and operators to build a self-healing capability into DAPTs by maintaining synergistic integrations of human-centric elements with automated diagnostic and control processes. An author proposes a hybrid theoretical framework for robust and resilient control design in which the stochastic switching between structure states models unanticipated events and deterministic uncertainties in each structure represent the known range of disturbances. The author proposes a set of coupled optimality criteria for a holistic robust and resilient design for DAPT. The authors in Literature have described a general technique: passivity and a particular controller structure involving the resilient power junction. In literature, the author gave a new simple characterization of the maximum number of attacks that can be detected and corrected as a function of the pair (A, C) of the system and we show in particular that it is impossible to accurately reconstruct the state of a system if more than half the sensors are attacked. In addition, the author has shown how the design of a secure local control loop can improve the resilience of the system. When the number of attacks is smaller than a threshold, the author proposed an efficient algorithm inspired from techniques in compressed sensing to estimate the state of the plant despite attacks. In literature, design a resilient end-to-end message protection framework, REMP, exploiting the notion of the long-term key that is given on per node basis. This long-term key is assigned during the node authentication phase and is subsequently used to derive

encryption keys from a random number per-message sent. Compared with conventional schemes, REMP improves privacy, message authentication, and key exposure, and without compromising scalability and end-to-end security. In literature, the author has designed resilient controllers for Cyber-Physical control systems under DoS attacks. We establish a coupled design framework which incorporates the cyber configuration policy of Intrusion Detection Systems (IDSs) and the robust control of dynamical system.

8. Secure DAPT Architecture

Defence Optimization: In the recent years, the DAPT have paid much attention to some security issues, such as safety, security, reliability, resilience, dependability, etc. In particular, the need for combining security theories with the attacks which DAPT is facing, and provides recommendations and defences. The DAPT security architecture we put forward successfully addresses these issues. The DAPT security architecture can be designed from three aspects. One of them is DAPT security theories, which contains security objectives and basic theories. Security objectives provide a sort of goals which DAPT should achieve. Without security objectives, such as safety, security, reliability and resilience, we could not know in which conditions DAPT cannot operate healthily and in a stable manner. Basic theories usually contain information theory, control theory and game theory, which provide theoretical support for DAPT research. In past the researcher had attempted various methods to build the secure architecture for DAPT. In literature, the author adopted a hierarchical viewpoint to these security issues, addressing security concerns at each level and emphasizing a holistic cross-layer philosophy for developing security solutions. The work proposes a bottom-up framework that establishes a model from the physical and control levels to the supervisory level, incorporating concerns from network and communication levels. The literature proposed a novel adaptive control architecture for addressing security and safety in DAPT. Specifically, the author developed an adaptive controller that guarantees uniform ultimate boundedness of the closed-loop dynamical system in the face of adversarial sensor and actuator attacks that are time-varying and partial asymptotic stability when the sensor and actuator attacks are time-invariant.

3.2 Domain-wide Technology Application:



	Normal CP / L freq.	Opt. CP / L freq. / L latency	Small CP / H freq. / L latency	Extended CP
Subcarrier BW	15 kHz	30 kHz (2x15 kHz)	60 kHz (4x15 kHz)	$(n \times 15\ \text{kHz}, n = 1,2,4)$
SF duration	500 µs	250 µs	125 µs	500/n µs
OFDM symbol, duration	66.67 µs	33.33 µs	16.67 µs	66.67/n µs
CP, duration	4.76 µs	2.38 µs	1.19 µs	16.67/n µs
OFDM symbol incl. CP	71.43 µs	35.71 µs	17.86 µs	83.33/n µs

The technologies mentioned earlier are now incisively applied to the 5 domain areas which are detailed below domain-wise.

3.2.1 DAPT on Telecommunications

Industry 4.0 is driving the trends for digital transformation. Digital transformation is the change associated with the application of digital technology in all aspects of human society. The transformation stage means that digital usages inherently enable new types of innovation and creativity in a domain, rather than simply enhance and support traditional methods. Key trends for digital transformation under Industry 4.0 include IoT, AI, Edge computing, Block-chain, and communication with guaranteed delivery service with less than a milli second time constraints for many applications. Following this trend – since everything can be digitized, transformed, transported and stored, the ubiquitous telecommunication infrastructure will also need its transformation into digital infrastructure at Scale. After considering many applications like Industry 4.0 Rel-16 to support IoT, Video Analytics, AI enabled applications, vRAN, AR/VR, security etc. we conclude that there are four enablers for this massive transformation as mentioned below:

1. Industry 4.0 – 5G hyper connection and innovative Air Interface
2. Massive scale Transport- Ethernet/IP, TSN.
3. Low Latency computing at network scale e.g. MEC
4. Massive “softwarization” where applications are, converging to IT methods e.g. Virtualization etc.

This research group will focus to leverage DAPT to resolve the above four challenges to create a massive innovation engine around Mass Scale Industry 4.0

transport, Low Latency Hyperconverged Computing & Massive softwarization for automation and control to support Industry 4.0 applications. We propose the following for creating an automated, high performance, programmable and deterministic network to support Industry 4.0 compliant next generation real-physical system development:

Proposal 1: Industry 4.0 Hyper Connection and Innovative Air Interface

IEEE and 3GPP 5G and Industry 4.0 standardization has emphasized on ultra-reliable low latency communication (uRLLC) in their standards viz. REF- 3GPP TS 22.861, TS 22.821, TS22.804, TS 22.806, TS 38.916, TS 22.891, TS 22.862, TS 22.863 3GPP TS 22.885 3GPP TS 22.864 and few more. The ultra-reliable low latency communication (uRLLC) is most innovative feature for Industry 4.0 for mission critical communication, industrial automation like reliable remote action with robots or coordination among vehicles and even the production line. Industry 4.0 targets at wireless communication link with guaranteed communication for more than 99.999% of the time. It also defines that different parts of a system or a machine or even a workflow need not be physically attached as long as they can use mission critical ultra-reliable links to work together. Here the virtual radio access network (vRAN) will handle all traffic with enhanced vertical and horizontal performance.
Industry 4.0 demands the most stringent key performance indicators (KPI)viz. latency, jitter, packet loss rate (PLR), no inference andmulti-tenancyin both vertical and horizontal traffic pane. The upcoming IEEE 802.1 REL-16 also focuses on uRLLC. There are feasible ways to achieve these stringent requirements such as: the transmission time interval (TTI)can be shortened by 1/5th of LTE TTI (2 OFDM symbol) while sub-carrier spacing can be reduced for the symbol time by giving less access to network and sub-block level pipelined frame processing is used to reduce the latency. Flexible Numerology for different waveform and flexibility can be used by band sizing and transmission diversity based redundancy can be leveraged for reliability with no-retransmission protocol. This can be achieved by using co-ordinated Beam Forming for same data to mitigate the path loss etc.We also see concurrence in Industry 4.0 – 5G Air Interface definition and TSN definition in IEEE as shown in the Table.1.

Table.3.1: Concurrency between IEEE definitions and TSN standards

IEEE TSN	Type	Std Detail	Analog to 3GPP 5G function	TSN STD
802.1ASrev	Synchronisation	Timing & Synchronization	SSB, SIB & TA	Synchronisation
802.1Qbv	Latency	Timing aware shaping (per queue based)	Time Aware Schedule	Latency
802.1Qbu	Latency	Frame pre-emption	Inter-UE Pre-emption	
802.1Qch	Latency	Cyclic queuing and forwarding	Configure Grant	
802.1Qcb	Reliability	Redundancy (Frame replication and elimination)	Dual connectivity	Reliability
802.1Qci	Reliability	Pre-stream filtering and policing	Resource control	
802.1Qcc	Resource management	Enhancements and improvements for stream reservation	Radio resource management	Resource management

In Industry 4.0 standards, low latency can be achieved by using new numerology, slot, mini-slot or bidirectional structure-based scheduling while downlink can be multiplexed between uRLLC and eMBB services by using pre-emptive scheduling and by granting the uplink a free transmission leading to reduced processing time with short PUCCH (one or two symbols). High reliability can be achieved by using blind repetitions (i.e. K-repetition), micro-diversity (e.g. Rank-1 MIMO), slot-aggregation for PDSCH and PUSCH, multi-slot PUCCH and with configurable BLER targets for CQI report. URLLC MCS/CQI PDCP layer data duplication allows a packet to be transmitted on two different carrier. Accordingly, to map the above requirements on TRANSPORT and MEC, we will face bounded latency/Jitter per hard slice with no opportunity of re-transmission. Load distribution in transport can then be obtained using LAG and ECMP, however, supporting a target BLER near 10^{-1}retransmission in LTE delivering a tail latency up to 1 sec with a BLER of 10^{-9} and latency of 1msec will be the challenge.

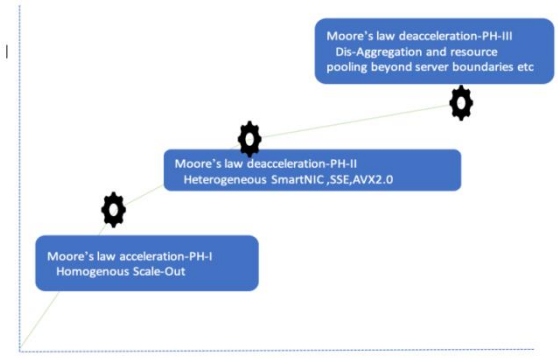


Fig.3.1 Why resource disaggregation in essential in next generation computing.

Proposal 2: ***Heterogeneous and disaggregated computing at the edge – Next Generation computing evolution***

Resource disaggregation is the key technology in next generation computing. Fig. 3.1 shows that the way how compute requirements are variably intense at the burst of data. A static hardware on the edge will be highly unsuitable to such dynamic loads and results into sever mismatch to deliver high performance in real-time. We will develop new standards, innovative hardware and software protocol stacks for disruptive adoption of DAPT for developing Industry 4.0 compliant backbone for Smart IoT and intelligent cyber physical system.

Following are a few flagships uses cases:

1. *Hyper Converged 5G-IoT Edge*

   There will be a shift of computing to the edge, as India's businesses will take advantage of the benefits of cloud and hyper-converged infrastructure to deal with increasing data gravity. While the legacy three-tier architectures are already struggling to cope with high volumes of data generated by today's enterprises, Fig.3.2 depicts how 5G-IoT will be the catalyst to drive edge computing and IoT. The Indian IoT market is expected to touch $9 billion by 2020 across sectors such as telecom, health, vehicles and homes, among others. We will be witnessing a significant growth in the adoption of new-age technologies such as IoT, AI and Cloud across industries with edge-computing environments to support the reality of AI-driven IoT.

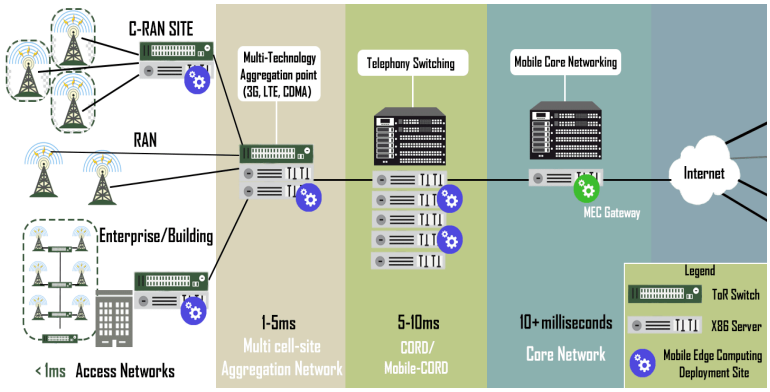


Fig.3.2 How operators will modernise networks with edge computing.

2. *AR/VR/Video Analytics use cases on Multi-access Edge Computing (MEC)*

Two of the hottest trends currently taking entertainment by storm are augmented reality (AR) and virtual reality (VR). The success of apps like Pokémon Go and the addition of virtual reality headsets to the vast majority of mainstream games consoles has seen the popularity of both AR and VR skyrocket and MEC technologies are being looked to in order to take AR and VR to the next level. Imagine the scenario, when a person walks down the street, or through a mall, doing some window shopping. Their eye is caught by a store window display with a large, high-definition video screen. Next to this is a mannequin dressed in a haute couture. The person pauses in front of the screen and there is a life-size image of them, wearing the outfit. In order to function properly, both augmented and virtual reality require the fastest possible response times and low latency communications, making multi-access edge computing an ideal partner [R1].

[R1] Pham QV, Fang F, Ha VN, Le M, Ding Z, Le LB, Hwang WJ. A survey of multi-access edge computing in 5G and beyond: Fundamentals, technology integration, and state-of-the-art. arXiv preprint arXiv:1906.08452. 2019 Jun 20.

3. AI/ML enabled in computing

Leveraging AI/ML technology, companies can implement an all-in-one server add-on that runs seamlessly in the background, scanning and analysing user entriesor machine status in real time. It can even be configured to block duplicate user sign-ins or detect faults as they happen. The AI/ML solution does this by automatically matching user/ machine data and by comparing data points such as username, email, phone number, address, Social Security numbers, linked credit cards, IP data and more or it matches with meta data related to machine faults. There is no need to run custom queries or reports, saving time and human capital. Applications of AI/ML in Industry 4.0 scenario have been shown in Fig.3.3.

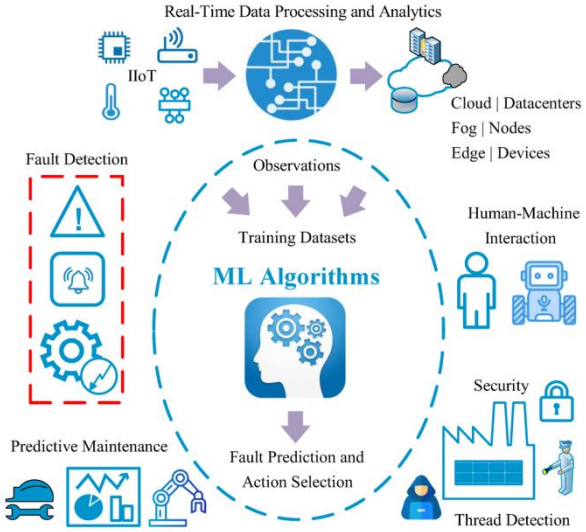


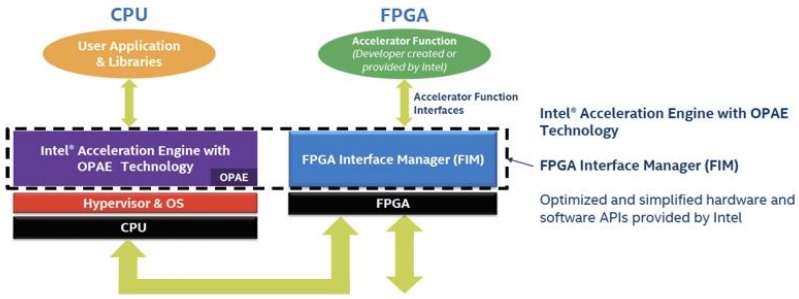
Fig. 3.3 Applications of AI/ML in Industry 4.0 fault detection, prediction and prevention [R2]

[R2] Angelopoulos, A.; Michailidis, E.T.; Nomikos, N.; Trakadas, P.; Hatziefremidis, A.; Voliotis, S.; Zahariadis, T. Tackling Faults in the Industry 4.0 Era—A Survey of Machine-Learning Solutions and Key Aspects. Sensors 2020, 20, 109.

4. Software abstraction for FPGA

With more parallelism and sensing, we receive flood of data, with which we need to automate decision-making, to have real-time insights into what connected devices are telling us, and present interactive and intuitive user connections to this data. Without accelerated computing, scale-out of many applications (e.g., artificial intelligence)

will prove impractical. New computing requirements demand more parallelism, lower power consumption, and a degree of flexibility never before seen in accelerators. To meet this need, hardware platforms—from the edge to the cloud—have been evolving to include mixtures of CPUs and accelerators. FPGAs play a



critical role in the trend toward heterogeneous computing platforms that are highly parallel, power-efficient, and reprogrammable. In short, FPGAs enable hardware performance with the programmability of software as shown in Fig.3.4.

Fig.3.4. Processor acceleration environment for FPGAs [R3]

[R3] Intel. 2020. Enabling FPGAs For Software Developers. [online] Available at: <https://software.seek.intel.com/enabling-fpgas> [Accessed 3 May 2020].

With Industry 4.0 standards the vRAN based solution delivers carrier grade reliability and predictable performance, low-latency, unrivalled manageability and orchestration, massive scalability, optimized resource utilization, and flexible deployment options as well as the ability to quickly launch new services through network slicing and service chaining. The vRAN solutions mitigate deployment risk and accelerate time-to-market.

Proposal 3: Development of Command and Control Centre for Smart City Test Bed at IIT(BHU) TIH

Under Industry 4.0 revolution, approximately 500 billion devices are expected to be connected to the Internet by 2030. Each device includes sensors that collect data, interact with the environment, and communicate over a network. The Internet of Things (IoT) is the network of these connected devices. These smart, connected devices generate data that IoT applications use to aggregate, analyse, and deliver insight, which helps drive more informed decisions and actions.

The IoT will be the critical part of CPS to run business strategies going forward. Based on an IDC study of 2300 executives in 15 countries, 48 percent of those

surveyed have already deployed IoT solutions, and 58 percent said that the IoT is strategic to their business strategy (discussed in Chap 1).

TIH on DAPT will improvise the functionality of the Internet of Things (IoT), and we can know more from data-derived intelligence and real-time surveillance. And by being more aware of what's happening in our operation, we can find ways to make it work better.

Challenges related to all this additional data—like limited bandwidth and processing capabilities—can lead to "stranded intelligence" and lost opportunities.

Accordingly, a centralized Gateway will be created to connect and monitor common challenges in IoT environments where devices and applications are highly distributed. It will help us connect the Edge and Fog Processing Module (EFM). This platform will support all the proprietary devices, collect massive amounts of data, and turn it into information which helps us gain advantages likecost reduction, efficiency through digitization and automation, remote monitoring, preventive maintenance, safety for personnel and real-time quality assessments.

Building blocks for Command and Control Centre

1. Integrated IOT Software Platform: A central gateway will connect distributed devices ("things") to the network and then extract, normalize, and securely move data from those devices to distributed applications as shown in Fig.3.5. This platform also plays a vital role in enforcing policies defined by data owners, as to which data goes where, and when. This distributed system of software streamlines your IoT operations by performing three key functions.

Fig.3.5 Command and Control Centre for Smart City Scenario

Gateway for Command and Control Centre will:

- **Extract data** from disparate sources ("things"), regardless of protocol and transform it, making it usable by the applications that provide business value.
- **Compute data** anywhere from edge to destination to provide processing where it's needed. This enables fast decisions at the point of action, dramatically reduces latency, and makes most efficient use network resources.
- **Move data** programmatically to get the right data to the right applications at the right time. The platform serves the need for data distribution in multi-cloud, multi-party, and multi-location situations — executing policies to enforce data ownership, privacy, and security.

2. **Core & Access Switch:** Core and Access Switches deliver efficient design and functionality across both modular and fixed configuration switching platforms for the IoT fabric. They provide the network foundation for a flexible and agile 3-tier or spine/leaf architecture. The Cloud Scale technology for IOT enabled Switches provides the following capabilities:

- **Scaling:** Responding to advances in application development and use of containers and microservices, it takes advantage of the expanded transistor capacity of its next-generation switch ASIC to increase route and end-host scale.
- **Bandwidth capacity:** The use of next-generation technology has enabled. to build a single switch-on-a-chip ASIC that can support line-rate routing capacity. It also enabled. to build a full VXLAN-enabled top-of-rack (ToR) switch.
- **Smart buffering:** Algorithm improvements, combined with more ASIC die space available for buffers, allows us to implement smart buffering for comparatively larger internal buffers (40MB versus 16MB). Smart buffering also provides an intelligent congestion control mechanism for IP storage which uses IP-based technology to access storage devices using TCP/IP networks.
- **Telemetry/visibility:** With ASIC technology, we will be able to provide full flow information and increase the amount of flow telemetry almost fivefold at reduced cost. IoT enabled Switches with IoT Cloud Scale ASICs will support the data analytics platform for pervasive visibility into the applications and infrastructure. These capture every packet and every flow at line rate with no impact on the CPU. These provide new sources of analytic information such as an enhanced flow table, buffer monitoring, and expanded counters to complement the diagnostic functions in the

current generation of switches. With this next generation of ASIC, capabilities such as segment routing, group-based policy security, network service header, and full-featured VXLAN overlays are possible at higher scale and in more efficient devices.

3. **Core Router:** This router will be positioned as WAN routers in the network and will be responsible for aggregating all the different application traffic residing and flowing in the network. The core router will be hosted in the DC and will provide connectivity between all the different applications hosted inside the DC and their respective end-points installed/positioned in the field network. It will also act as the egress point for the entire Smart city Network through its peering with the Internet Service providers.

   IoT Enabled routers offer us a compelling set of value propositions that distinguish products from competing solutions. It is backed up by a full suite of supporting products, architectures, and guidance to help transform your network into a platform for business excellence. Building on the success of existing platforms, the IoT Enabled routers can assist us in achieving business success by providing services securely and reliably, while helping to minimize TCO.

   We will achieve several important advantages such as efficient and redundant hardware and software over the infrastructure with redundant common components, embedded services processors (ESPs), RPs, fans, and power supplies.

4. **Network edge security for attack prevention and compliance:** This interface offers the ability to turn on embedded security services instantly, without affecting routing performance. Additionally, built-in integrated security services can reduce the need for standalone devices by providing control packets, computation of routes, and connection setup, as well as multiple threat control services.
5. **Modular operating system:** It Uses Software, a modular OS designed to accommodate strict requirements for security and high availability.By implementing a next-generation network (IP NGN) solution powered by the IoT enabled switches, we will gain an innovative system architecture.

- **Perimeter & Data Center Firewall:** To effectively mitigate risk and address modern threats, Next Generation Firewalls (NGFWs) must controltraffic via traditional port and protocol methods. NGFWs must deeply analyze and correlate applications, users, traffic, and files. The Next-Generation Firewall (NGFW) will be the industry's first fully integrated, threat-focused NGFW. Available as physical

and virtual appliances, NGFW mitigates advanced threats faster and streamlines IT security operations. With NGFW, we can stop more threats and get more from your network. Proposed NGFW configuration includes Application Visibility and Control (AVC) for Layer 7 application, user control and the tightly integrated Next-Generation Intrusion Prevention System (NGIPS). NGFWs uses threat intelligence from the Talos Security Intelligence and Research Group (Talos). NGFW provides industry-leading contextual awareness and threat protection. Talos is the elite technology group includes over 250 security researchers and threat analysts. It works with the industry's largest collection of real-time threat intelligence using myriad tools, including big-data machine learning, advanced forensics, and intelligence cultivated and curated from IIT(BHU) and third-party threat feeds. Threat intelligence is informed in the form of 100 terabytes of security intelligence daily with 16 billion daily web requests processed over 1.5 million daily malware samples and 600 billion daily email messages. This technology group continually updates NGFW threat feeds. This hones NGIPS, Security Intelligence and AMP capabilities. This NGFWs receive updates related to NGIPS signatures, acquires intelligence for indicators of compromise (IoC) correlation, AMP signatures and AMP Threat Grid malware intelligence and details about malicious or suspect URLs, IP addresses, and DNS servers.

6. **Network Behavior Analysis:** Stealth watch is the most comprehensive visibility and network traffic security analytics solution that uses enterprise telemetry from the existing network infrastructure. It provides advanced threat detection, accelerated threat response, and simplified network segmentation using multilayer machine learning and entity modelling. With advanced behavioral analytics, we are always informed about, who is on our network and what they are doing. This is a single, agentless solution which allows visibility across the extended network, including endpoints, branch, data center, and cloud. And with Encrypted Traffic Analytics, Stealth watch technology will be the only product that can detect malware in encrypted traffic and ensure policy compliance, without decryption.
7. **Industrial Switch:** Industrial switches are connected to Pre-Aggregation layer which in turn would provide connectivity through the service provider network to the Data Centre ASR router. IE switch can be configured with multiple VLANs for sending traffic to/from Pre-aggregation nodes. IE switches will be used to provide

wired connectivity to all street layer devices like Root Access Points, IP CCTV Cameras, Kiosks, PA systems, Variable Messaging Signboards etc.

Industrial grade switches will be placed at the network edge. WiFi RAPs (Root Access Point), CCTV Cameras etc will be terminated on IE switches via Ethernet port. Below are some of the functional requirements for each of such nodes viz. access ring physical media built on fibre, dual single mode rugged SFPs have been considered in each of the IE switches to create a ring. The SFPs can support a distance of maximum 10 kms. Access ring will terminate on a pair of pre-aggregation nodes or on a single pre-aggregation node if possible (depends on fiber feasibility) for improved redundancy. All the access rings are preferred to be dual homed. Total number of Box/PTZ cameras, Outdoor Wi-Fi access points terminating on a single IE Switch with Multi-VLAN support (IEEE 802.1q) on the IE Switches to ensure traffic isolation at a L2 level and DSCP and COS support for end-to-end QOS in the network. The REP (Resilient Ethernet Protocol) will be configured for ring protection to achieve sub 50 ms failover. The switch will be a rugged switch sustaining under harsh outdoor environments. The switch is IP 30 certified and will be DIN Rail mounted inside a junction box placed near the junction. The switch also supports IEEE 1588 PTPv2 for time synchronization.

8. **IoT Gateway:** Industrial Integrated Services Routers are compact, ruggedized routers designed for deployment in harsh industrial environments. The IR809 is the smallest multimode 3G and 4G LTE wireless router, making it an excellent solution for distribution automation and remote asset management across multiple industrial vertical markets. The IR809 has an integrated 9.6 to 60V DC power input and is designed to withstand hostile environments, including shock, vibration, dust, and humidity, and supports a wide temperature range (–40 to 60°C and type-tested at 85°C for 16 hours).

   The IR809 supports enterprise-class wireline-like services, such as quality of service (QoS) with advanced virtual private network (VPN) technologies (such as Dynamic Multipoint VPN (DMVPN) and Flexible VPN (FlexVPN) along with multiple virtual routing and forwarding (VRF) instances for cellular highly secure data, voice, and video communications. IOx, is an open, extensible environment for hosting applications at the network edge. The IR809 also extends connectivity

to include low-power wide-area (LPWA) access using the Interface Module for LoRaWAN.

9. **VC unit:**A seamless video conferencing solution Webex DX80 will be utilized for easier collaborations over video to meet with people as if we are in the same room. The Webex DX80 offers a dedicated, always-on HD video communication system with an IP phone that provides essential features for knowledge workers and a high-quality audio system for speakerphone with a screen that provides an engaging experience for video calls. A multitouch capacitive touchscreen provides an elegant and powerful user interface as a self-provisioning device that is simple for users to take out of the box and start using quickly. Easy "One-Button-To-Push" (OBTP) calling that integrates with common calendaring programs. Flexible registration models on-premises and in the cloud through Webex provides the ability for administrators to use the platform for secured connection with their remote workers
10. **Video Conferencing Codec:** The Tele Presence SX80 Codec provides a powerful and flexible platform for creating the ultimate video collaboration experience. The SX80 was built with the integrator in mind to support flexibility and creativity for customized video collaboration rooms that delight customers.

    It incorporates high-definition video collaboration applications into large meeting rooms, boardrooms, and purpose-built or vertical application rooms. Examples include training, briefing, and demonstration rooms, as well as auditoriums.

    The SX80 delivers up to 1080p60 end-to-end, high-definition (HD) video. It's the first in the industry to offer support for H.265, which lays the foundation for future bandwidth efficiencies made possible by the new standard. The codec offers a comprehensive input and output set and flexible media engine. It supports three screens to help enable a variety of use cases adaptable to your specific needs.

    This offers three SX80 integrator packages to reduce the need for external equipment and the overall cost of deploying video in larger meeting rooms. The packages include:

    - SX80 Codec and PrecisionHD 1080p 4X camera for smaller room scenarios
    - SX80 Codec and Precision 60 Camera for larger room scenarios—currently the best image quality in the market
    - SX80 and the SpeakerTrack 60 dual camera system, which features a unique, direct, fast switching approach for active speaker tracking

By including a Precision 60 Camera in the back of the room, it will give presenters a "stage" with Presenter Track. This feature supports automatic detection and tracking of presenters, following them as they stand up and move about at the front of the room.

3.2.2 DAPT on Power

DST initiated R&D Programmes in the areas of Data Science, Technology, Research and Applications Programme in 2014 to promote Data Science discipline, 1) Sensor Networks & Web Enablement (SNWE) was initiated as a sub-Programme in 2008 and 2) Cyber Security Research Initiative (CSRI) was initiated in 2009 as a research Programme. These research areas are initiated keeping in view of the developments at the International arena and also relevant in Indian context. Fundamentally, these are sensitisation programmes aiming at basic research, awareness building, capacity & Capability building, HRD and technology development. Only seed R&D grants are provided to very small groups of advanced researchers. DAPT is a new and emerging technology; as such there is no outcome overlap with any other schemes/ sub-schemes undertaken by Ministries/ Departments. However, DAPT is a converging and fusion technology and there could be its significant application to the various missions undertaken by the different ministries. Some of the examples are:

(a) Ministry of Electronics & Information Technology (MeitY), GoI has schemes on Cyber Security, electronic manufacturing, e-Governance, SMART technologies etc.

(b) Department of Heavy Industries (DHI) has mandated to implement technologies related to Industry 4.0 (I4.0) which basically talk about Robotics, Artificial Intelligence (AI), SMART manufacturing etc.

(c) Ministry of Energy, Non-conventional energy sources are working on SMART Grids, energy optimisation etc.

(d) Defence Research & Development Organization (DRDO) is working on autonomous systems, intelligent machines, AI based secured communications etc

(e) Ministry of Urban Development is working on SMART Cities

(f) Ministry of Surface transport is working on SMART transport systems

(g) Ministries/Departments of Agriculture, Health, Water resources, Education, Telecommunications are working on implementation of IoT/ AI based systems.

Further, DAPT is an Inter-Ministerial National Mission, as part of Mission implementation. The above activities build a strong R&D backbone to develop technologies and applications.

At IIT (BHU) the entire plan DAPT on Power would be executed in two work packages. The work packages with the details are as follows.

1) ***Work Package 1:*** Solar PV integrated smart hybrid power processor with multi-directional power flow architecture

Fig. 3.6 shows the architectural details of this work package. In this work package, smart power inverters capable of giving ac and dc bus simultaneously will be designed and developed. As shown in Fig. 3.6, power input may be from solar PV or utility grid. AC and DC busses are running parallel and EV charging infrastructure is the part of the smart home architecture in which power may flow from EV to home as well as home to EV. The charged EV may act as a backup generator in case of a weak grid scenario. The maximum extraction of power would also be ensured from the solar PV even in the partial shaded condition. Data from the solar PV would be collected and analysed. Artificial Intelligence (AI) based algorithms would be developed to track the maximum power point in case of partial shaded condition as shown in Fig. 3.7. Moreover, based on the data at the load and input (both from solar PV and distribution grid) nodes of one smart home, tie line power conversion unit would be developed to facilitate power flow from one home to other according to the demand and availability. Thus, the homes may also share power amongst themselves with the tie line conversion as shown in Fig. 3.8.

Further, laboratory test beds are used to study the performance of the complex network such as transmission/distribution grids, power architecture of the microgrids. Laboratory scale models of sources, power lines and emulated loads are used to replicate the power network. A smart home is also similar to a small microgrid and may be referred to as a nanogrid. In the futuristic smart homes, load emulators can be designed which can emulate any home load with a given current profile which may include harmonics and thereby, providing a test bed in the home environment itself. The existing power electronic converters may be used for this purpose where the present and futuristic load

profile may be predicted based on the available current, voltage, power, and harmonic data in the home environment. A preliminary prototype with off-the-shelf components is designed and run using DSP is shown in Fig. 3.9.

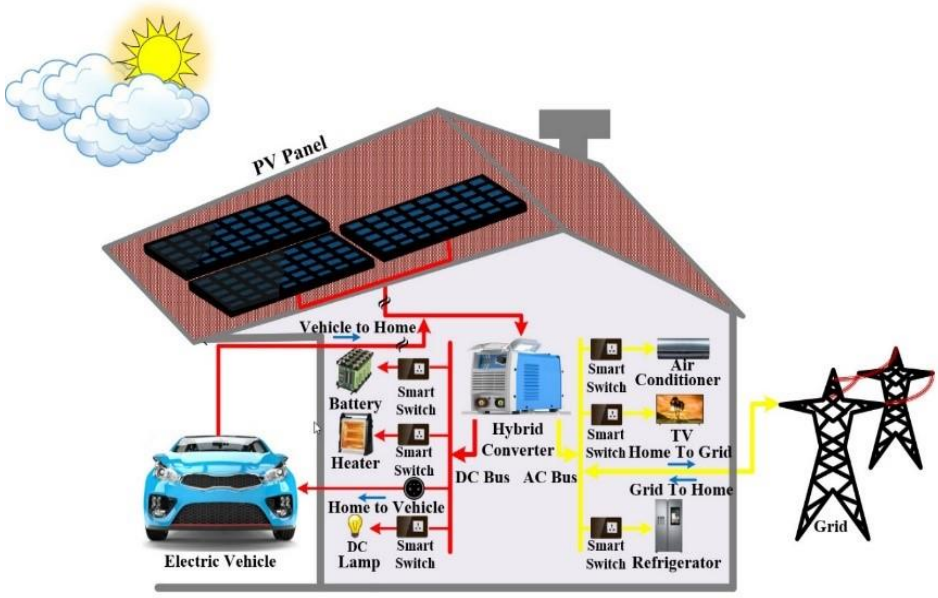


Fig. 3.6. IoT operated smart home.

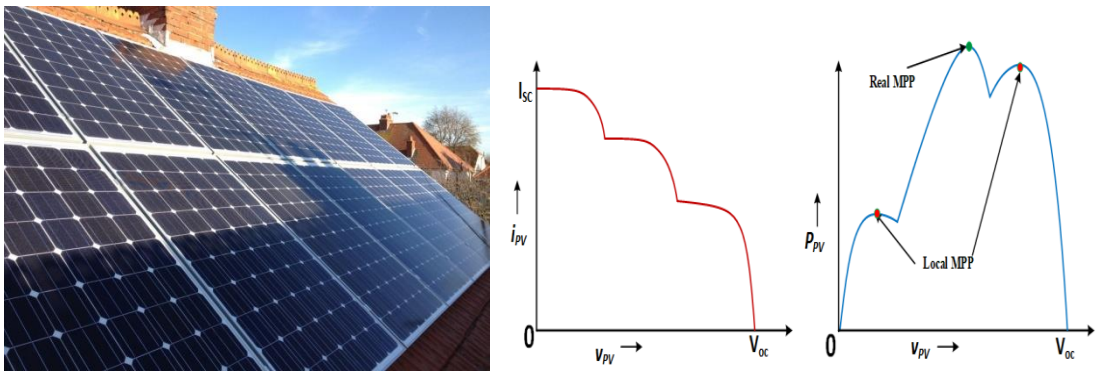


Fig. 3.7 Partial shaded condition with characteristics.

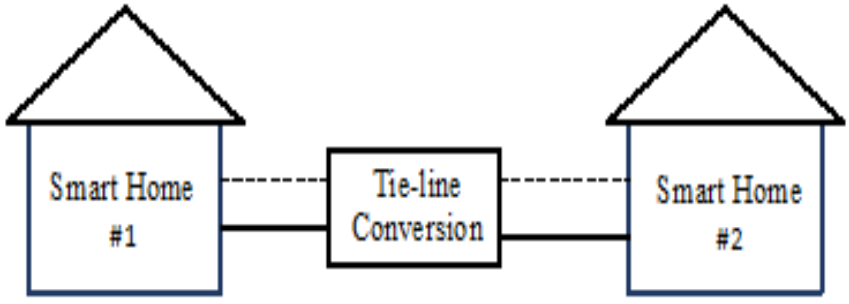


Fig. 3.8 Power transfer between the homes with tie line converter.

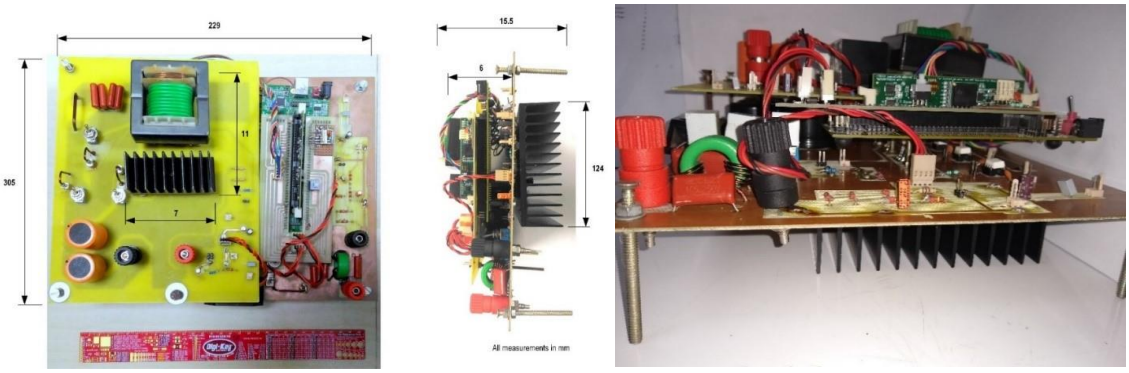


Fig. 3.9 DSP based power converter for reconfiguring power converter to predict load behaviour. (S. R. Meher, S. Banerjee, B. T. Vankayalapati, and R. K. Singh, "A Reconfigurable On-board Power Converter for Electric Vehicle with Reduced Switch Count" *in IEEE Transactions on Vehicular Technology, January 2020*.)

Some of the technological areas related to this work package on which the cutting-edge researches can be done are as follows:

i. Hybrid power converter adaptable for both AC and DC supply
ii. PV system operation under partial shaded conditions
iii. Leakage current minimization in transformer-less PV system
iv. Harmonic mitigation in grid injected current

2) <u>Work Package 2:</u> Technology development for remote operation of smart devices through IoT

All the devices in the smart homes will be IoT activated in order to control them remotely. The system representation has already been given in Figs. 1.2 and 1.4. The Fig. 3.10 illustrates the generic data-driven model for IoT operation. The first step of the proposed model is to collect the significant amount of historical data under different working conditions for tuning the machine learning model. The data collected using various sensors needs to be articulated for removing noise, missing values, outliers and so on. Further, various time, frequency and time-frequency domain features will be extracted for designing the feature set and then the feature set will be transformed or optimized for eliminating the redundant information from the feature set. The transformed/optimized feature set will be utilized for the learning of intelligent algorithms to improve the prognosis or diagnosis results. The main characteristics of the model would be

a) Identifying the promising data access points.
b) Improve the accuracy of data-driven approach
c) Reduce the computational complexity of intelligent methods.
d) Design self-improving model based on online/offline data

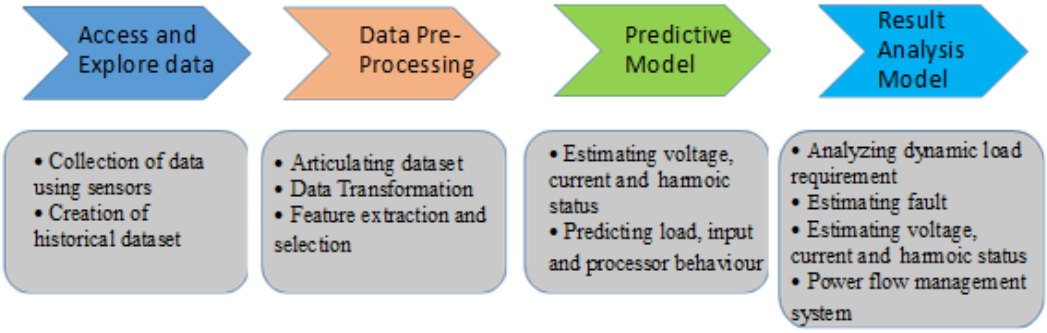


Fig. 3.10 Generic workflow model.

The technological areas on which the research can be done for this work package are as follows:

i. Smart reconfigurable house
ii. IoT enabled demand response management in distribution system
iii. Environmental prediction model for IoT based smart agriculture
iv. Smart microgrid infrastructure with power optimization

3.2.3 DAPT on Defence Research and Development

Technologies and Mission Strategy

Five critical technologies viz. semiconductor, superconductor, digital,computer, and algorithm technologies appear to be common to all sensor types,and careful delineation of these greatly simplifies the difficulties of projectingfuture sensor capabilities (Reference from Technology for the United States Navy and Marine Corps, 2000-2035 Becoming a 21st-Century Force, Volume-2). Whenever information is required, sensors are utilized to make the physical measurements from which the desired information is extracted. Radar, optics, and sonar sensors, through the active or passive exploitation of the physics of wave propagation, give information about distant objects that is useful for general surveillance and situation awareness as well as for more specific purposes, such as real-time target location and weapon guidance. Other sensors, such as position-sensing devices or inertial sensors, produce useful real-time local measurements that can be used to control all kinds of platforms, including whole ships, steerable radar or communication antennas, and gun mounts on ships, or even individual missiles in flight, depending on just where the sensors are located. Yet other sensors produce measurements for which the long-term variations in the measured parameters

provide the useful information. For example, temperature or atmospheric pressure sensors can supply inputs for short- and long-term weather prediction, whereas acoustic sensors mounted on rotating machinery can provide evidence of bearing wear or imminent gear failure, thus triggering needed repair and maintenance procedures. In short, Military heavily dependents on the use of sensors today, and the future seems to promise even broader use of sensors as the technology continues to evolve toward more capable performance and the demand for more and better information escalates. Miniature sensors combined in a single package with on-board, integral computational capabilities to form mini-systems-on-achip are future sensor systems. An intriguing prospect for the future is the notion of interacting armies of small, capable, autonomous entities—microrobots that fly or crawl or swim—that combine miniature sensor packages with integrated computers, actuators, power sources, and wireless communication capabilities. This kind of implementation of sensors suggests the possibilities of higher overall performance in surveillance, for example, through adaptive, autonomous spatial repositioning of the individual sensors.

Technology Development

Mission has wide-ranging activities ranging from promoting high-end basic research and development of cutting-edge technologies in sensors, on one hand, to service the technological requirements of the common man through the development of appropriate skills and technologies on the other. The mission supports research and developments activities through a large number of schemes/ programmes/ missions, most of which see human resource development also happening.

Major components under Technology Development sub-mission is classified into three categories depending upon Technology Readiness Level (TRL):

i. Expert-driven new knowledge generation /Discovery (TRL 1-3)
ii. Development of products /prototypes from existing knowledge (by experts or teams) (TRL 4-6)
iii. Technology /product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology, demonstration of full working technology (by experts or teams) (TRL 7-10).

Areas of Research

A. Development and Implementation of 3D Geospatial data for Defence based Surveillance, Planning & Strategies

Geospatial data plays an important rolefor the defence purpose planning and strategies. 3-Dimensional geospatial data provides the details of object in depth, breadth, and height. Three-dimensional stereoscopic image evaluation and visualizations help to get qualitative and quantitative information about an object.3D visualization generation can be viewed from any angle which helps for analysis operations through scene-based or object-based and helps to quantifying object information. Further Machine learning techniques, data analytics, IoT and ICT infrastructure along with 3D geospatial data can play important roles in defining solutions that help to build and ensure the complex planning and chalk out the strategies. The aim of this project will be to develop very high-resolution accurate 3D model, orthophoto, DSM and other geospatial database for defence purpose and use it with 3D stereoscopic display along with hand tools for efficient planning and strategies in defence.

Following broad objective has been proposed for the project.

- To generate accurate 3D model for planning of defense related strategies.
- To generate accurate and high resolution Orthophoto, Digital Surface model (DSM) and Geospatial database for planning.
- Cloud based image collection through drone and ground mounted cameras for surveillance.
- To publish all the data in web server so that multiple stakeholders can access, analyse through machine learning techniques and plan various components using the data.
- Development of geo-fencing for movement tracking & surveillance purpose.
- 3D stereoscopic display platform along with hand tools for efficient execution of different geospatial queries and algorithm based on data analytics.

Accurate and details geospatial data is the base for planning. UAV based Photogrammetry and laser scanning is one of the proven techniques to develop high resolution 3D maps and other geospatial data like orthophoto, DSM, hyper-spectral thermal images. After the advent of automatic image matching techniques, UAV photogrammetry becomes an emerging source of data collection for surveying of large areas. UAV based photogrammetry is a low-cost alternatives to the manned aerial photogrammetry and field based surveys. Similarly UAV based LIDAR is very efficient

method for collecting the point cloud data in areas under tree cover or vegetation. UAV mounted with GPS, Inertial Measurement Unit (IMU), Multispectral and Thermal camera may be used for accurate 3D mapping and generating relating products.

In this study following steps will be taken to generate geospatial data using above techniques.

- Establishing ground control point in the study area using DGPS and total station.
- Making flight plans for study area and overlapped aerial images will be collected of study area.
- Using GCP and aerial photographs collected in the field, 3D model, orthophoto and DSM will be generated.
- All major features will be digitized as vector data in GIS environment and different attribute will be added.
- Cloud based system will be developed for image collection and their interpretation through machine learning algorithms. These images will have the properties of hyper-spectral and thermal though Drone and ground mounted cameras. Machine learning and Data analytics-based algorithm will be developed and specifically used for the planning and scenario analysis including predicting capability.
- 3D stereoscopic display platform will be developed and different hand tools will also be developed to interact with 3D stereoscopic display platform and to execute the spatial queries and scenarios where 3D spatial data will be used as baseline data for planning and management of different activities. Geo-fencing model will be developed which will help to track the soldiers and to plan their roots and movement. Further it will be used to manage surveillance.
- The data created can be hosted in web server and different solutions like network analysis, spatial analysis tools of GIS can be used for further analysis of data.

The proposed work outcome will consist of the methodology for data capturing through drone and other surveillance camera. Outcome will consist of IoT, Data analytics & ML based platform which will help to analyse the different images and other input data as per the requirement of defence. A 3D stereoscopic display platform will also be created for planning purpose.

The proposed work will help the defence in several aspects such as,

- Proper planning of movement of troupes and keeping them in the territory through geo-fencing. It will help to plan the trip of soldiers.

- Images collected with UVA mounted hyperspectral sensors and thermal sensors along with spectral signature library provide means for surveillance and reconnaissance against difficult-to-detect targets.
- Hyperspectral imaging can be used for feature detection and identification which may include targets such as military vehicles, camouflages and various man-made Materials. Thermal Mapping can be used for surveillance and reconnaissance against difficult-to-detect targets, under covered and night vision.
- Target detection and identification which includes targets such as military vehicles, camouflages and various man-made materials, detecting the movement disturbed surfaces.
- 3D stereoscopic display platform will help for group planning. It will help for implementation & visualization of different scenario Aerial photographs to generate 3D Map of any area for Defence planning. Analysis of the view shed (i.e. area visible) from the desired location, construction of search towers. Demarcation of search area for conducting effective search operation.

B. 5G for Defence

Communication and exchange of data is very important and crucial in battle field. New war equipment need good data and in real time. Further, different kind of sensors will also be deployed for getting the different parameters of field. 5G technology can fulfil the said requirements. Therefore, it is desired to deploy 5G technology for defence purposes. But, there are many challenges in deploying the 5G technology. In view of different challenges following objectives can be thought at the initial stage that can be enriched further.

Following broad objective has been proposed for the project.

- To make a testbed for 5G defence related use cases testing and development.
- To evolve jamming techniques for 5G networks
- To identify the algorithms for increase the jamming margin
- To deploy and networks sensors in battle field
- To identify the algorithms for self-backhaul

First of all, a testbed will be required for test and characterization of different algorithms and parameters. Testbed will typically require signal generator and signal analyser. The control architecture will be built on top of that. For research purpose, FPGA can be used

to have control plain. Higher layers can be developed on the basis of Orean standards. After development of testbed, different jamming and anti-jamming techniques can be implemented and tested.

- Testbed that can be used for end to end testing by using UE, supporting handoff and device to device communication.
- Jamming algorithms with different methods particularly narrow band jamming for downlink
- Anti-jamming techniques with significant SNR improvement with minimum change required
- Sensor network algorithms

C. Chemical and Biological Sensors

Although sensing chemical or biological substances remotely at a distance is possible through the **LIDAR**, most chemical and biological sensors rely on direct physical contact between the sensor interface and the unknown or sought-for substance. The threat posed by chemical and biological weapons together with the opportunity afforded by modern optical and digital technology is driving the rapid development of new sensors. Portable, sensitive, fast, inexpensive sensors for chemical and biological sensing are needed for field use today, and development activities in this arena are increasing. The Defense Advanced Research Projects Agency, for one, has mounted a major thrust/application, emphasizing the detection and identification of biological agents(Reference from Technology for the United States Navy and Marine Corps, 2000-2035 Becoming a 21st-Century Force, Volume-2).

In view of above the following sensors will be developed for defence:

i. Lab-on chip:

Chemical sensors are major requirement of military due to continuous testing of environment. Testing of Air, Water and Solid materials including explosives are major requirement for military personals even they are not in war situation. These sensors are possible by development of miniaturised sensors like Lab-on chip. FETs and Electrochemical sensor are getting attention in detection of toxic chemical and also biological materials (biosensors). In this are the major focus will be given on development of indigenous sensors and implantation for defence applications. The priority will be on Gas, Water and Food sensors for safety of military personals.

ii. Microelectromechanical Systems

In view of bio-war and use of novel bacteria and viruses during the war the MEMS technology is showing enormous potential for detecting and recognizing biological materials. Among the miniature mechanical components that can be fabricated in MEMS are microfluidic components, such as tiny valves and pumps, which can be configured to create an integrated DNA amplifier based on the PCR process. Recently, we have seen the application of PCR in detection of Corona Virus (COVID-19). However, it was limited due to requirement of conventional PCR and sophisticated lab. This will be addressed by using miniturized system behaving like PCR or rapid detection kits based on antibody-antigen interaction.

iii. Body wearable sensors

Readiness of solider is crucial at war time. There is requirement of body wearable sensors for soldiers to get real time data of pulses, BP, Serum glucose level and metal stress. Sensors based on electrical signals will be developed for reediness of solider. Miniaturised sensors will be developed to measure various parameters and communicate to a central data system.

iv. Explosive detection

Sensitive detection of explosives is a challenge for army during the war as well as terrorist threats. Detecting explosives has also become a very complex due use of wide variety of materials as explosives and the lack of easily detectable signatures. Nanosensors have the potential to satisfy all the requirements for an effective platform for the detection of explosives. These sensors will be developed and signature for various explosives will also be developed for the defence.

v. Smart sensors for soldiers (Air, Water and health)

Chemical sensors are major requirement of military due to continuous testing of environment. Testing of Air, Water and Solid materials including explosives are major requirement for military personals even they are not in war situation. These sensors are possible by development of miniaturised sensors like Lab-on chip and wearable smart sensors. FETs and Electrochemical sensor are getting attention in detection of toxic chemical and also biological materials (biosensors). In this are the major focus will be given on development of indigenous sensors and implantation for defence applications. The priority will be on Gas, Water and Food sensors for safety of military personals.

D. Microwave techniques for imaging including object detecting radars

Through-the-wall microwave imaging is one of the important emerging microwave techniques in the recent years. Such an imaging system provides enhanced situational awareness in a variety of military applications. Such systems not only detect the presence of the targets behind walls, but also provide information concerning each target's location, motion, size, and backscattering cross section. Many approaches have been attempted in testing through-the-wall radar imaging techniques. The most widely used approach is the wideband or UWB radar mechanism, which contains an antenna array, or one antenna measuring at multiple locations to form a synthetic aperture. The bandwidth covered is typically from a few hundred MHz to several GHz [Wenyi Shao and Todd McCollough, , IEEE Microwave Magazine]. The backscattered signals are generally measured by all antenna elements in the array and are calculated to produce an image. Such systems are proposed in present DPR for imaging of hidden objects or objects behind the wall or any obstacle.

E. Stealth technique based on advanced polymer composites

Most of the airborne objects are prone to be detected by radars using the X and Ku frequency band of microwave. Considering the range, where the threat of detection is maximum, there is an emergent need for developing materials in which the absorption occurs in the frequency range of 1-20 GHz. The uses of ferrite as absorbing materials are becoming very significant. In addition to that Inherently Conducting Polymers (IPCs) are also finding their application as absorbing materials for electromagnetic radiation. These polymeric materials also provide processing ease for coating or application of materials for microwave (MW) absorption. However, IPCs suffer from other issues like stability and mechanical strength. Composites based on polymers like metal/polymer, carbon nanotube–epoxy etc. has been reported to overcome these issues. A possible solution is to employ IPCs with conventional polymers blend along with magnetic nanoparticles. The blend will provide extrusion possibility and ease in processing of materials and better distribution of nanomaterials in the polymer matrix with control on physical and structural properties. The metal oxide functionalized materials will provide excellent absorption and stability to the polymer (especially IPCs). Broadband RADAR absorbing advanced materials will

be developed based on magnetic nanoparticles and Inherently Conducting Polymers composites. These composites will be used as coating materials for stealth applications.

F. Power systems for operating sensors in remote areas

The defence vehicles need to be operated in adverse condition which requires batteries for electrical power support. To enhance the life and reliability of theses batteries optimal battery charging is very important feature to be taken care. There are several issues associated with battery charging for defence vehicles such as battery charging infrastructure, battery size, charging connections supported by the vehicles, capacity of power supply etc. An optimal charger within a vehicle that can handle various charging profile will be necessary for future. Interdisciplinary Data Analytics and Predictive Technology will help in designing the optimal battery charging scheme for the defence vehicle. The DAPT based charger will increase the life of battery without increasing the weight, size and cost of the system by exploiting the existing electric traction motor and power electronics circuit. The data will be collected in from of various values of the voltage and corresponding current values in various charging states and conditions. These collected data will be used as look-up table, the analysis of which will be used to predict a model to design optimal charging control for battery.

G. Advance Polymer Composites

Soldiers need better protection against new ballistic threats and the overall weight of body protection is also required to reduce to increase the comfort of soldiers. Apart from these advanced materials are required for uniforms and tents of the soldiers to keep them warm at high altitudes and also escape from the radars of enemy. These issues may be addressed by development of novel polymer nanocomposites with following objectives:

(i) To promote translational research in DAPT and associated technologies.

(ii) To develop technologies, prototypes and demonstrate associated applications pertaining to defence priorities.

(iii) To enhance high-end researchers base, Human Resource Development (HRD) and skill-sets in the emerging area as mentioned above.

(iv) To enhance core competencies, capacity building and training to nurture innovation and start-up ecosystem.

(v) To establish and strengthen the international collaborative research for cross-fertilization of ideas.

(vi) To set up world-class interdisciplinary centers of excellence at IIT (BHU), that can become repositories of core expertise in DAPT and related areas and serve as focal points for technology inputs for the industry and policy advice for the government.

(vii) To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects.

(viii) To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system.

(ix) To address some of the National issues and development of sector-specific solutions.

Expected outputs/ Deliverables

Objectives	Expected outputs/ Deliverables
To promote translational research in DAPT and related technologies.	Increased core researchers base, Start-ups and spin-offs
To develop technologies, prototypes and demonstrate associated applications pertaining to national priorities in DAPT	A set of technologies, tools, algorithms to feed into some of the national priorities
To enhance high-end researcher's base, Human Resource Development (HRD) and skill sets in these emerging areas.	Creation of next-generation technocrats, Scientists, Engineers, Skilled and semi-skilled workforce.
To establish and strengthen the international collaborative research for cross-fertilization of ideas.	Global standard Collaborative research for some of the India specific issues.
To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.	Start-up companies, job creation and economic growth
To set up world-class interdisciplinary centers of excellence at IIT (BHU), that can become repositories of core expertise in DAPT and related areas, with a substantial amount of funding to enable them to achieve significant breakthroughs.	Dedicated translational research centers aimed at taking Academic output to Industry/Market
To involve Government and Industry R&D labs as partners in the collaboration centers. Incentivise private participation to encourage professional execution and management of pilot scale research projects	Enhanced participation of private industry in R&D, PPP model demonstration in technology development
To tie up with incubation centers and accelerators to foster close collaboration with entrepreneurship eco-system	Enhanced delivery mechanism
To address some of the National issues and development of sector-specific solutions.	Technologies to address some of the national issues.

3.2.4 DAPT on Road Transport and Highways

Smart mobility and transportation can be enhanced through data analytics and predictive technologies. IIT (BHU) proposes two major work plans namely (1) Highway Knowledge Centre where a multitude of data would be collected, borrowed and fused together to support transportation decision making, and (2) Intelligent Transportation Systems which includes testing relevant transportation algorithms and systems for real-time traffic management control system. Further subtopics are summarized in Figure 3.11 and detailed below.

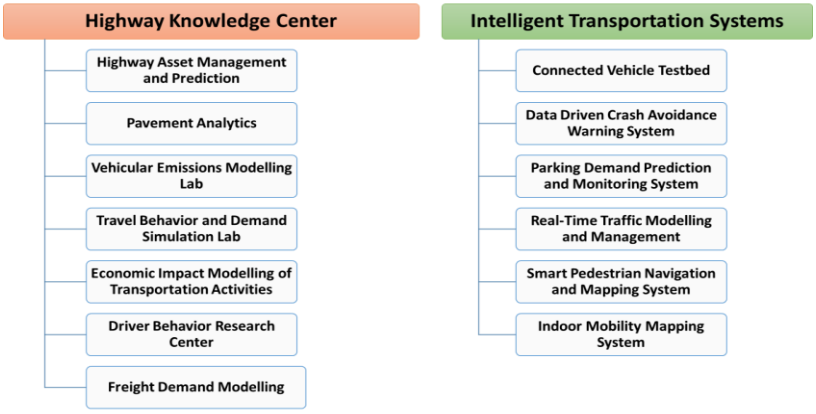


Figure 3.11 Details regarding the subtopics in DAPT applied to transportations.

Highway Knowledge Center

The Highway Knowledge Center would provide data, testing and modelling facilities for highway asset management, pavement analytics, vehicular emissions modelling, travel behavior simulation, economic impact modelling, driver behaviour research and freight demand modelling and prediction.

- Highway Asset Management

The highway is a source of continuous data that can be used effectively for predictive maintenance of pavement, road infrastructure, and bridges. The center would facilitate continuous data collection using a multitude of sensors that would be used to create performance report and identify failure triggers for timely alert and maintenance. Traditional methods of manually keeping track are time taking, challenging and unreliable.

- Pavement Analytics

There are no dynamic systems readily available that can provide real-time response of traffic on the pavement condition and quality. Sensor data can be used for modelling

pavement condition and distress using real-time temperature, moisture content and dynamic load in the form of vehicles (See Figure 3.12). The facility would be useful for non-destructive pavement material modelling, testing and prediction. These data along with location based weigh-in-motion information can open up a huge opportunity for pavement research and predictive maintenance.

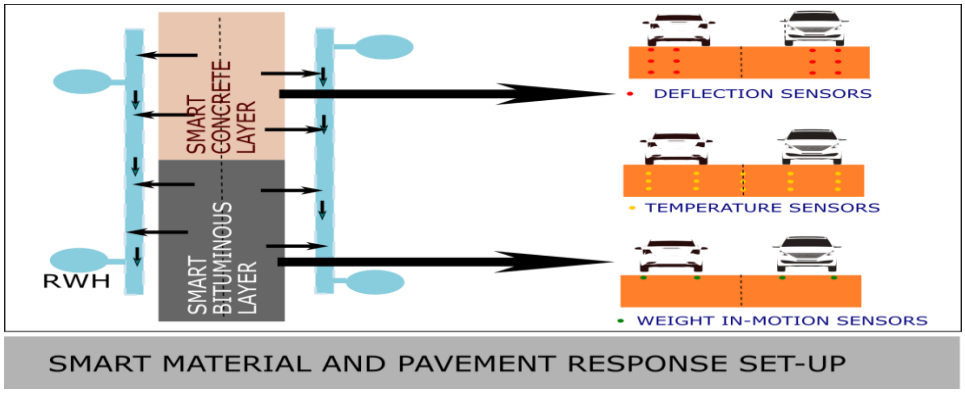


Figure 3.12 Smart material and pavement response setup

- Vehicular Emissions Modelling Lab

  Presently, we inherit the emission standards developed in Europe and customize them to our conditions. However, to more closely reflect vehicle heterogeneity and lane free traffic prevailing in India, there is a need for conducting elaborate on-road and dynamometer emissions testing so that environmental impact and fuel consumption can be predicted more accurately.

- Travel Behaviour and Demand Simulation Lab

  Often predicting travel behaviour at large distance and time scale is crucial for accurately estimating economic impacts of transportation or being proactive in fulfilling the expectations and needs of a multitude of transportation users. In the absence of proper travel demand models, the system would either remain underutilized or exceed the capacity. The proposed travel behaviour and demand simulation laboratory at IIT (BHU) would collect travel behaviour and choice data and develop simulation models to test various future scenarios such as (1) How would people travel post a global pandemic? (2) How is the demand for air travel affected by introduction of high-speed rail?

- Economic Impact Modelling of Transportation Activities

  Through economic impact modelling, the Highway Knowledge Center would model the factors affecting toll collections, increase in property values amidst

transportation improvements and increase in mass transportation ridership. These models would help evaluate the economic benefits of given transportation system or policy.

- Driver Behavior Research Center

  Driver is the most important entity that cause road inefficiency, increased air pollution, and highway crashes and fatalities. Human factor research is at its infancy in India since we have been using the parameters that were developed primarily for developed nations. Very limited or no research exists in India where the credibility of these parameters has been evaluated against the policies that are formed. Driver behaviour research includes in-lab driving simulator as well as on-road driver monitoring and data collection van. Together, these can open up huge opportunity for driver behaviour research to find results that would be more meaningful for the Indian community.

- Freight Demand Modelling

  Modelling freight demand and the factors affecting it is important for economic models. The center at IIT (BHU) would use a multitude of sensors including the weight-in-motion sensors, truck volume counts from origin to destination and type of commodity transported to provide data-driven freight transportation prediction.

Intelligent Transportation Systems (ITS)

Unlike Highway Knowledge centre where the data is mostly used in its historical form, the center within ITS workplan would collect, analyse and monitor real-time traffic and road users. The following are the description of each subsection.

- Connected Vehicle Testbed

  Traffic microsimulation has shown that when vehicles are connected (see Figure 3.13) to a centralized system, where each vehicle/driver is aware of the nearby vehicles, road geometry, real-time weather conditions, visibility, traffic signal configuration and real-time status, the dynamic message signs and other relevant information can guide the drivers in safely and efficiently manoeuvring through the traffic. This technology is still evolving even in the most developed part of the globe. There is an opportunity for India to become a pioneer in this area by developing technologies, algorithms and solutions applicable to developing countries like India. With the array of sensors (computer vision, radar, Lidar), this system will create two

data banks that would enable algorithms and hardware testing for (1) extracting relevant traffic parameters, and (2) building customized IoT technologies for transportation safety and management applications. This will create opportunities for developing technologies and applications that have not been explored in the developed countries. There is a great opportunity to build a prototype model for a smart city as well as a single location which would facilitate research, algorithm testing, and future scenario analysis in specific as well as interdisciplinary areas.

The vehicles and road side units would also be integrated with a Smart Signals Testing System. Traditional traffic signal is a useful tool to manage traffic on an urban road. There is an opportunity to optimize the vehicle movement on a corridor by implementing signal coordination which minimizes the need for stopping at most intersections. While coordinated signals are very common in many parts of the developed world, they have not been common in India. A similar system is the signal pre-emption (or priority) system where particular vehicles (ambulance, police car) are given priority to clear the intersection by broadcasting the location of those vehicles so that they can clear the corridor/intersection as smoothly and quickly as possible. The effectiveness of these systems has not been studied leave alone implementing them in our cities. Signal pre-emption and management become even more relevant in India where road is at times used by non-conventional traffic in the form of possessions such as during wedding, funeral, religious ceremonies and festivals. The system would recognize such possessions in real time and would promptly act and manage the traffic to minimize delay and convenience.

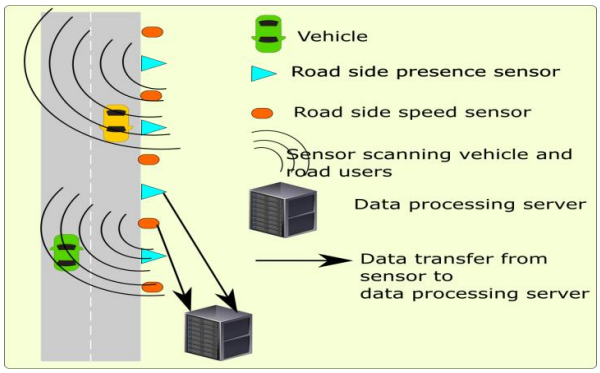


Figure 3.13 Illustration of a connected vehicle test bed

- Data Driven Crash Avoidance Warning System

  Many road accidents occur because the drivers fail to see the object (pedestrian, vehicles, and fallen debris and so on) that may suddenly appear on the road. We

can take the help of technologies to assist the drivers to become aware of objects that might on its path and act in a timely manner to avoid possible collision and associated losses. In this regard, three systems are more desirable namely (1) sight distance assist at intersections, (2) speeding behaviour detector and alarm system, and (3) pedestrian movement warning system. Figure 3.14 depicts the system. This system would enable the drivers to help avoid an object that may either already be on the path of the vehicle but not visible or is approaching the path of the vehicle. This system will be integrated with fog/visibility sensors that would continuously monitor visibility and issue warnings (road side message signs or overhead gantries) when it drops below a threshold. The system will also collect other movement data such as pedestrians and bicyclists which are allowed to use the sidewalks. The road-side sensors would continuously monitor such road users and would warn the incoming drivers in a proactive manner such that accidents could be avoided.

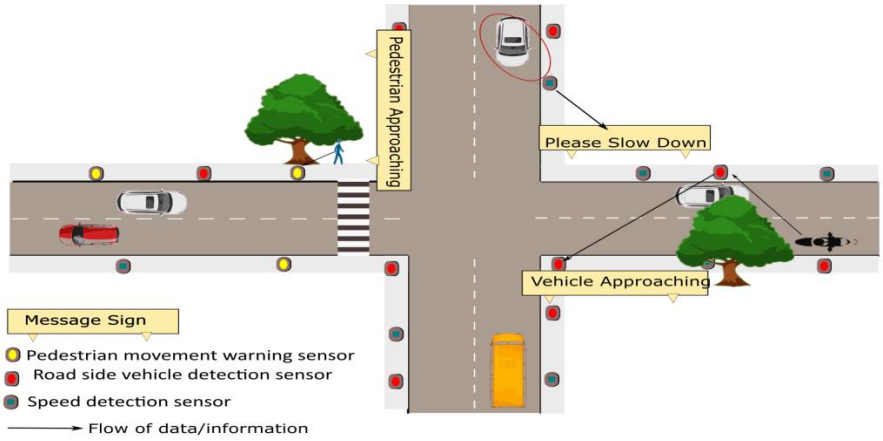


Figure 3.14 Crash Avoidance Warning System

- Parking Demand Prediction and Monitoring System

  As the city car population rises, the need for an automated parking system would be desirable to complement the density and the degree of complexity in handling vehicle parking. There is a need for an autonomous system that understands Indian conditions and behaviour. Implementing a city-wide parking system is challenging especially in a developing country where infrastructure is not readily supportive and there is a lack of systematic, standard and uniform implementation of rules and availability of devices and equipment. We are proposing a parking system that would incorporate practical situations and perform appropriate data fusion such

that parking state and availability may be predicted to a higher accuracy. The system would respect and adapt to local conditions, financial ability and other traffic management systems. The system would minimize the client's effort in offering a quick, easily maintainable, financially sound parking demand prediction and monitoring system.

- Real-Time Traffic Modelling and Management:

  Through DAPT extensive data collection and processing becomes optimized and therefore it can effectively manage road traffic in real-time. This includes real time traffic management to alleviate congestion in the network and real-time incident management to reinstate the road after a crash incident occurs. The process requires dynamically routing the traffic to minimize average delay for everyone. The success of such systems relies heavily on DAPT and robust sensor technology for collecting, analysing and disseminating information in a timely manner. Below is an example of a traffic management center.

- Smart Pedestrian Navigation and Mapping System

  With the increasing number of commercial and industrial buildings, concern for security and navigation is still an issue for pedestrians. The suggested center would identify every person entering the streets or building using an array of cameras placed at strategic position along with photogrammetry techniques. The system would be track the person's movements in the streets or building using edge computing, gesture recognition methods and internet of things. A database of all the person activities inside the streets or building would be recorded. A navigation system would be developed that would learn and evolve over time as more data regarding pedestrian's movement are captured. The system would store the activities inside the streets or building and solve the problem of indoor navigation where GPS or any other navigational system is not supported. The system would primarily use only cameras along with edge-computing, the need for various other sensors is eliminated and the system would require minimum band width for data exchange with the servers.

- Real-time Indoor Mobility Mapping System

  Indoor Mapping of different buildings like hospitals, schools, banks, archaeological monuments, religious places, government offices and other public spaces is

important. With the help of artificial intelligence (like deep learning techniques) and sensors (including thermal cameras) indoor positioning system can be developed. This system would help the administrators in disaster management, indoor planning, planning of events, inventory management, building evacuation and surveillance by various enforcement agencies.

3.2.5 Health and Family Welfare:

(a) Technology

The healthcare target problems would be selected based on already-available quantitative estimates of National-level Disease Burden [Health Metrics will be based on the standard parameters which are used in clinical praxis, namely DALY units, i.e. Disability Adjusted Life Years]. Similar approach is considered by Health technology policy makers both internationally or in India (e.g. W.H.O., U.N.D.P., Ministry of Health, GOI, and Dept. of Biotechnology, GOI).

The DAPT-Healthcare Mission's ambit covers the sustenance and protection of a healthy brain and mind, throughout all spans of the human ageing process. This lifespan perspective is important, as a caring nation needs to enhance the life across all its citizens: both men and women, and along the 3 broad age groups as one journeys through life:

Infancy/Childhood (0-20 years), Adulthood (20-60 years), Senescence (above 60 years).

To paraphrase, one needs to give utmost concentration to the homing and honing of affordable digital and engineering interventions to some tactical problem areas that can have a vast wide-ranging productivity related to the brain/mind health segment. The proposed interventions would utilize up-to-date contemporary analytics and predictivity solutions which would yield high precision screening or diagnostics, and individual-specific planning of treatment or therapeutics. These will accelerate the clinical efficacy and performance of Health Tech intervention, enabling one to usher in healthcare as being economical and within reach of the vast majority of populace.

Rationale of Data Analytics & Predictive Technologies:

A main focus is harnessing these technologies for developing Neuro informatics Platforms for:

1. Development of tools and databases for management and sharing of neuroscience / psychometric data at all levels of analysis [Fig. 3.15].
2. Construction of tools for analyzing and modelling neuroscience / cognitive data, in normality and disease.
3. Formulation of computational models of the human brain, its neuronal processes and cognitive / perceptual /subconscious operations.….

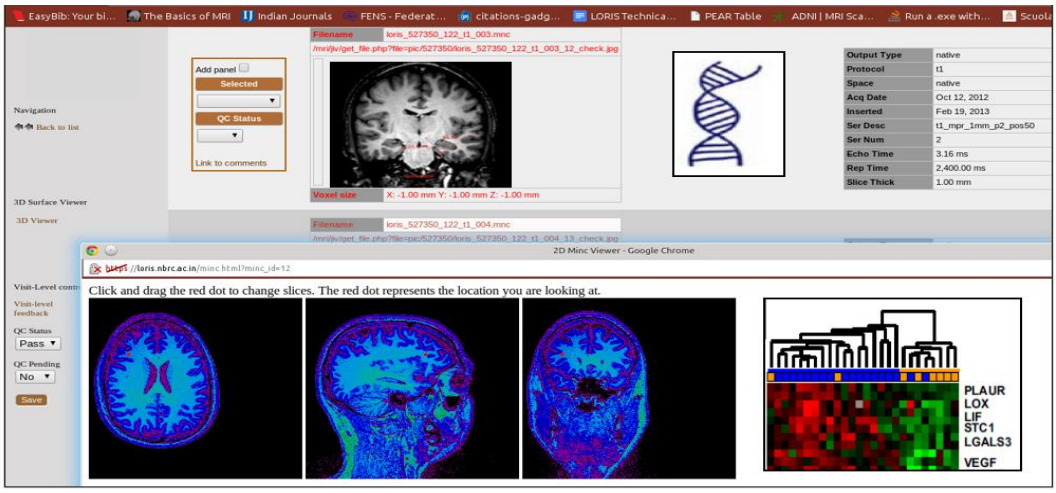


Fig. 3.15: Clinical Data, Signal and Image communication website and menus for uploading/downloading brain 3D images, EEG signals and Biochemical/Genomics data, accessible by any participant institution.

(b) Technology Matrix

The basic technology sub-domains for the DAPT on Brain/Mind Health across all ages, would be, as enumerated, across the three broad age groups:

Infancy/Childhood (0-20 years), Adulthood (20-60 years), Senescence (above 60 years).

Nevertheless, all these deal with the same system, the human brain: an electrically-firing network system embedded in a biomaterial, pulsing tissue. Accordingly, much of the Technological - Informatics techniques of investigation or monitoring, would be have similar layer of procedures, such as:

Genomic messaging, Electro-physiology, Circuitanalysis, Signal processing,

Imaging techniques, Stimulus-response mapping, Psychometric-cognitive Testing

Thus, one can conceptualize the methodological approach as a Matrix, with the Technology Verticals being the Age group, while the Technological Horizontals are the procedure layers mentioned above. The Technology Matrix is illustrated in the Table 3.2 below.

Table 3.2: Technology Matrix Verticals

[The number of + symbols imply the degree of involvement of the corresponding technologies (leftmost column) with respect to the diagnosis and treatment of brain/mind disorders in the relevant age group]

Parameters	Infancy/Childhood (0-20 years)	Adulthood (20-60 years)	Senescence (above 60 years)
Bioinformatics, Genomics, Neuron Circuit Analytics	+ + +	+ +	+
Electro-physiological, Neuro-Imaging, Psychometrics Technologies	+ + +	+ + +	++
Organism Models / Templates for Human Disorders	++	+ + +	+ + +
Neuronal Information Processing, Predictive Multi-scale Platforms	+	+ +	+ + +

(c) Technology Horizontals

The following items are the horizontals, being data-intensive techniques or methodologies of studying or tracking the behavior of the brain/mind system under varying conditions or disorders. The horizontals would consist of the following 4 layers of technologies:

(1) Bioinformatics, Genomics, Neuron Circuit analytics:

This will deal with investigations on molecular, genomic, and metabolomic profile of various cell types including both neuronal and glial cells, along with development and patterning of Neural Circuitry, and structural or functional Mapping of behaviour of the Networks. Further, the understanding basic glial cell dynamics and Neuron-Glia circuitry and crosstalk are critical to finding solutions for brain disorders, hence investments to this area are mandatory.

(2) Electro-physiological, Neuro-Imaging, Psychometrics Technologies:

There has been a seminal advancement of recording and imaging techniques and rigorous psychometric testing or assessments, for high-resolution studies and large-scale analysis of brain structure, function and development, including that for human investigations. Similarly there is a need to develop and promote human subject based studies and behavioural test battery scoring to complement research on psychology of development, ageing and other aspects of human subjects.

(3) Neuronal Information Processing & Predictive Multi-scale Platforms:

Multi-scale platform technologies will be developed to investigate and map (a) Signal transmission, (b) Information processing, (c) Computational operations, which occur among the three levels, and then the platform technology should actually be able to integrate and synchronize all the levels together. Using standard Auto-regressive techniques and Convolution Neural Network models, the platform would also have incisive ability of forecasting.

The technology verticals and horizontals would orchestrate together and usher in rapid, readily accessible, and accurate platform for analytics and predictivity solutions for high precision screening or diagnostics, and individual-specific planning of treatment or therapeutics (fig 3.16).

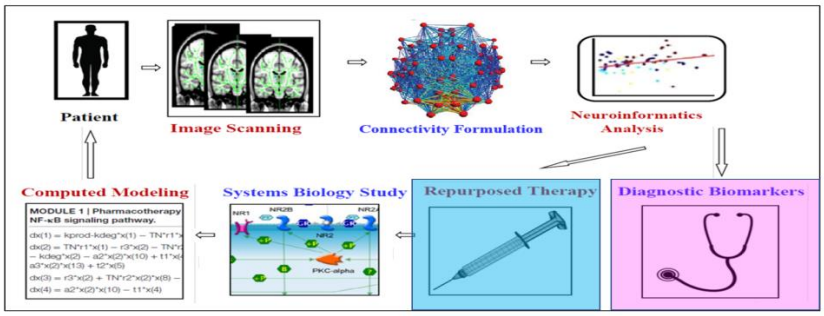


Fig. 3.16: Schema of applying Data Analytics & Predictive Technology for developing Diagnostics and Treatment modalities for Neurological diseases or Mental disorders.

(D) Technology Verticals

As indicated earlier, the basic verticals are the three broad age groups:

Infancy/Childhood (0-20 years), Adulthood (20-60 years), Senescence (above 60 years).

The methodologies associated with these 3 age-wise verticals are elucidated henceforth:

(1) Adult age-group-Amelioration of Brain Disorders by Neural &Behavioural Integration:

This would encompass enabling development of Techno-Economic NeuroCognitive Discovery Platforms. Construction will be undertaken regarding new Data analytics and Machine Learning based scientific discovery platforms to develop novel therapeutics (pharmaceutics, physiotherapy, behavioural therapy, electro-stimulation). Further, In-Silico Prototyping Platform to perform Computational Clinical Trials, shall be developed

under joint mentorship or facilitation by academia, industry and financial organizations. Two technology deliverables are envisaged:

Neurological Output:

Development of automated screening methods and optimal intervention for Cerebrovascular health as Stroke and Vascular Dementia (fig. 3.17).

Psychiatric Output:

Development of Causation Analytics formulation and preventive management of Acute Depression and its sequalae : Suicidal mentation.

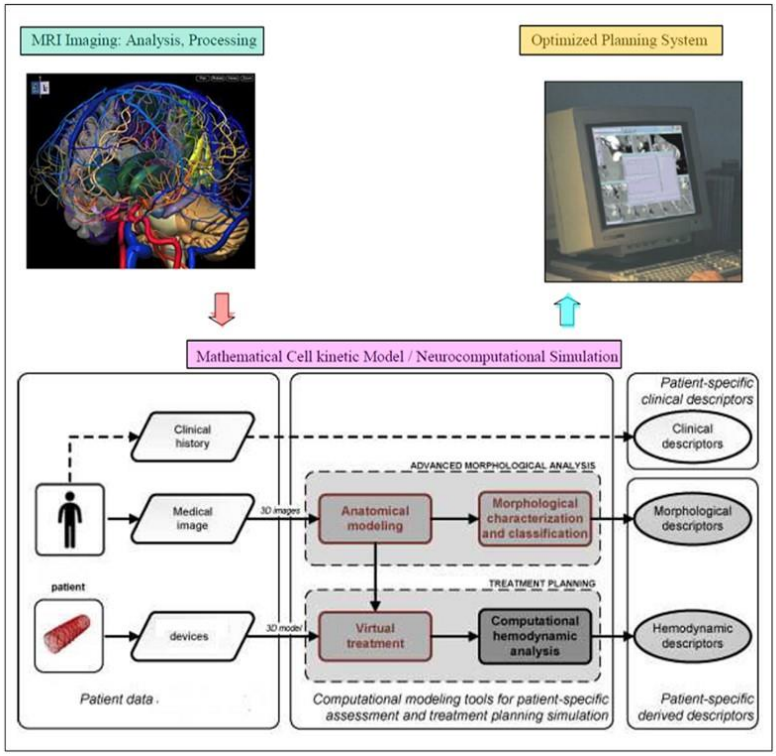


Fig. 3.17: Neuroimaging-aided Optimization of Neuroprotection therapy for Stroke, using varying combination of drug agents & faradic physiotherapy, across variable time window.

(2) Childhood age-group: Enhancing Brain Growth & Mental Development:

This would involve developing methodologies for Brain Protection and facilitating Learning & Intellectual Development (Educational Neurotechnology to ensure the "Demographic Dividend"). There shall be pursuance of multidisciplinary research on neuronal and cognitive basis of human learning, insight and creativity as the child grows and develops. One would pursue developing interventions for protecting brain from pathological stress in foetal, new-born, and infant situations, especially due to birth difficulties. This vertical will develop technologies for two deliverables:

Neurological Outcome:

Construction of digital methodology for Non-contact or minimally-contact prediction and management of asphyxia or chocking in infants.

Psychiatric Outcome:

Development of tablet-based screening methods and optimization of behavioral/cognitive intervention in Attention Deficit / Hyperactivity syndromes.

(3) Elderly age-group: Computational Bio-Engg. Modalities for assisting Disabilities:

This vertical would comprise developing Cognitive Stimulation to Postpone or Decelerate ageing-based Dementia. Utilizing tablet or mobile phone devices, technologies would be developed for aiding memory, attention and cognitive arousal, so that the irreversible setting of age-induced dementia is postponed appreciably. These methodologies will be used to formulate two technologies as the deliverables.

Neurological Outcome:

Construction of smart Neuro-assistive devices for incontinence of Urinary bladder and Rectal stool.

Psychiatric Outcome:

Patient-adaptive Monitoring and Stimulation Technology for maintaining or actuating cognitive and psychological reflexes, while ageing occurs.

3.3 Mission Strategy

With the Mission cut-out and its objectives defined, its success in terms of delivery lies on the strategy chalked out and of course, execution of the plan. The inherent complexity of the DAPT and the Mission to place India in a leadership position in this domain requires range of actions to be taken across the technology landscape, besides defining the instruments/ intervention that can be used to deliver. For this Mission, the technological landscape corresponds to the life-cycle of technology idea in the mind to the product in hand; spanning basic research, applied research, translational research, product development and commercialization. The knowledge/technology generation goes entwined with human resource development at multiple levels; at Under Graduate (UG) levels to tinker with the ideas, at Post Graduate (PG) and doctoral level to work further on these ideas often to prototypes, at faculty level to teach the basics and oversee ideas converting into prototype; the experts in the translational research carry those prototypes further into a market-ready product. After technology valorisation and

weighing the economics, entrepreneurs carry them further through their established enterprises or start-ups. There are gaps that innovations confront in the journey that sees them pitted with competing technologies or those existing and waiting for the ecosystem to favour them. The stage leading to commercialization and subsequent incremental innovations, also take human resource development alongside.

The interventions that can be deployed to deliver on these spaces could be in the form of Centers of excellence- which concentrate their efforts and resources in a chosen field, to maximize the return. Their delivery goes notches up, if they can leverage existing knowledge and expertise available anywhere in the world; it is here that intervention of International Collaborations, mostly facilitated through Science diplomacy, work the best by saving resources and time. The development of new knowledge or leveraging the existing one requires the involvement of the right type of motivated human resource, attracted through internship/ fellowship opportunities. It has been a common experience that only a fraction of technologies see the light of the day, most falling into the valley of death often due to last techno-managerial glitches. A push is needed at the last mile for a technology to get commercialized, through Innovation Accelerators. Further, the development and delivery of technology gets accelerated when challenged by a need; Top Level Challenges posed before the world and the competition induced by them often bring multiple technology solutions for the world at large. The strategy proposed shall be a multipronged, holistic and long-term one, to realize the emerging technologies like DAPT in the country. To realize the strategy, the **sub-missions or Programme under NM-DAPT** will include:

(1) **Technology Development:** through expert-driven research, Consortium based Research through Cluster-Based Network Programmes, directed research for the specific requirements of Industry, other Govt. verticals and International Collaborative Research Programmes

(2) **Centers Of Excellence:** Dedicated Centers to carry out domain-specific research, translational research, Innovation, Entrepreneurship development, start-up, training, and capacity building.

(3) **HRD And Skill Development:** through Fellowship Based UG/ PG, Ph.D., Post-Doctoral, Short Term Training for Faculty and National Workshops & Conferences etc.

(4) Innovation, Entrepreneurship and Start-Ups: To enhance core competencies, capacity building and training to nurture innovation and Start-up ecosystem.

(5) International Collaborations: To establish and strengthen the international collaborative research for cross-fertilization of ideas.

3.3.1 Technology Development

Mission has wide-ranging activities ranging from promoting high-end basic research and development of cutting-edge technologies, on one hand, to service the technological requirements of the common man through the development of appropriate skills and technologies on the other. The mission supports research and developments activities through a large number of schemes/ programmes/ missions, most of which see human resource development also happening.

Major components under Technology Development sub-mission is classified into three categories depending upon Technology Readiness Level (TRL):

1. Expert-driven new knowledge generation /Discovery (TRL 1-3)
2. Development of products /prototypes from existing knowledge (by experts or teams) (TRL 4-6)
3. Technology /product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology, demonstration of full working technology (by experts or teams) (TRL 7-10).

3.3.2 Centres of Excellence (CoE)

Centers of Excellence are emerging as a vital strategic asset to serve as the primary vehicle for managing complex change initiatives. In academic institutions, a center of excellence often refers to a team mandated to focus on a particular area of research; such an entity may bring together faculty members from different disciplines and provide shared facilities. In technology companies or institutions, the center of excellence concept is often associated with technologies or associated business, often human resource development is also in its folds. For an area like Data Analytics and Predictive Technologies based decision support systems, that bridges two distinct worlds- cyber and physical, is embedded in several technologies, feeds on ever-evolving technological advancements and finds application across the socio-economic as well as strategic sectors, CoEs are befitting instrument.

The objectives are to carryout translational research and establish world-class Center of Excellence in specific subjects of Interdisciplinary Data Analytics and Predictive Technologies based decision support systems in India. These CoEs would support and encourage innovative technology-based start-ups, industries, PSU that have an application and/or impact in the core sectors of the economy in our country. The Center of Excellence would also provide the incubation centers for start-ups with necessary guidance, tech support, infrastructure, access to investors, networking, and facilitating a host of other resources that may be required for the start-up to survive and scale.

Government and industry/ industry associations will be encouraged to participate. It shall be joint collaborative mechanisms that CoEs shall manage, contributed and monitored. Value addition and service provision shall be the driving force for CoEs. The existing and successful models and best practices shall be adopted while establishing CoEs. For India, there are few vertical focus areas that would be followed as guidance in terms of priority, such as

i. **Healthcare for all:** With current ratio of doctor to patient ratio of 1:1681, accessible & economical healthcare for all is almost impossible, unless we leverage AI for creating the technology middle layer that can leverage well trained doctors' expertise to all the remote corners of India
ii. **Smart city, Logistics & Mobility:** With autonomous and connected vehicles on the ground or in air mobility is going to redefine our cities, villages and connectivity within for people as well as businesses. Smart cities in future may not correspond to big cities, but with small cities connected seamlessly. Key policies need to be enabled to have this revolution.
iii. **Education & Future of Work:** DAPT will fundamentally disrupt the current skill driven employment cycle and education workflow, changing our perspective to creating lifelong learners. We would need to overhaul our people development plan to enable the next level of growth.
iv. **Financial Inclusion & Fraud prevention:** India still has 200m+ who are unbanked. With AI enabled speech and AR interfaces, they can access banking & credit anywhere with much lower amount of fraud. Specific policies adopting AI for banking will unlock this adoption.

v. **Smart Manufacturing &Retail :**3D Manufacturing tightly driven by data driven retail can bring in efficiency and make it globally competitive. This could drive new kinds of jobs with hyper connected small industries.

vi. **Cyber security &Defence: Core** aspect of centralized command and control is getting flipped with AI, allowing edge intelligence to enable faster response for cyber security & defence with 4 major objectives

   a. Enabling intelligent warfare
   b. Enabling remote warfare
   c. Enabling cyber warfare
   d. Enabling AI driven defence capability with predictive response

Under DAPT Mission, it is proposed to follow a technology life cycle approach, addressing all stages viz. Knowledge-Development-Translation-Commercialization, even at the macro-level. Therefore, it is proposed to create or set-up four-tiered Centers of Excellence (CoEs) as given in the Fig. 3.18. These are: International Centres Of New knowledge (ICON) focussing on generation of new knowledge and intellectual property; Centers for Research On Sub-Systems (CROSS) with focus on creating platform technologies with applications in diverse sectors; Center for Applied Studies, Translational research and LEadership (CASTLE) with focus on development and translation of technologies that are ready for deployment/ commercialization/ operationalization and benefit the end-users; and Center of Excellence in Technology Innovation and Transfer (CETIT) with focus on delivering products/technology ready for deployment or commercialization building up from an idea or concept.

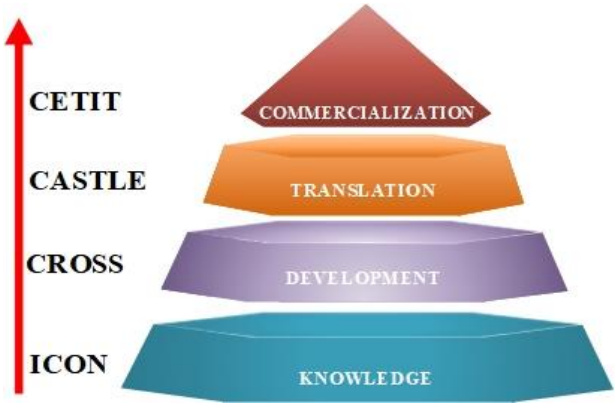


Fig. 3.18: Planned activities under the proposed Centres of Excellence.

Public Private Model & Revenue Model

A public private and revenue model as shown in Fig. 3.19 would be in place especially for CETIT. This would ensure that research output have Industry buy in and thus are relevant to some extent.

However, it is difficult to attract private capital without proof of pilot in place, especially in a country like India, even for cutting edge areas of research such as DAPT. Thus, initial pilot phase would be driven by Govt. funding and in later years for Scale and growth phase, it is planned to bring in 20-30% capital from private pools, with majority of that capital coming in post 3 years, where enough output would be visible to private capital.

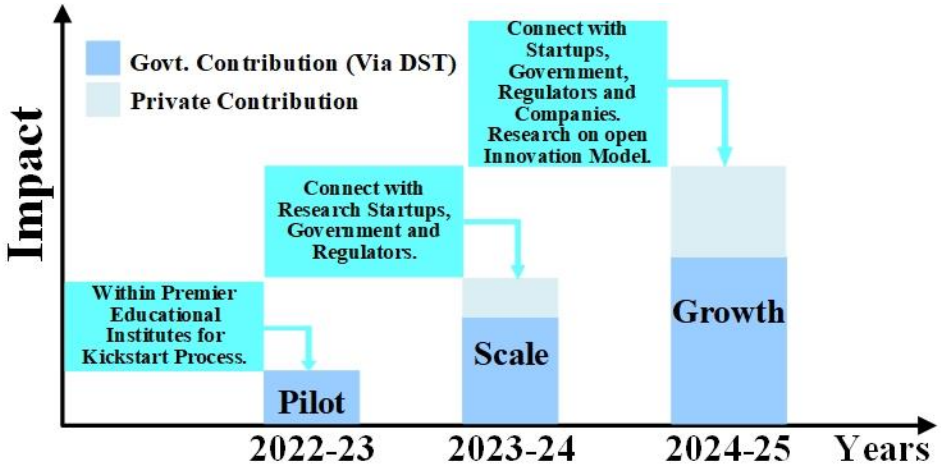


Fig. 3.19: Proposed Public-Private Model.

The core area of output will be five revenue channels as given below with a focus on creating a self-sustaining model post initial 5 years of investments.

a. **Applied AI & Engineering -** R&D sponsored by Industry, Govt. or Start-ups leading to outputs in forms of innovative product or services that can be leveraged by them
b. **IP Creation and Licensing (could also lead to new ventures) -** Selecting a few ideas to co-create with Start-ups or Industries or Government with an aim to spinning it off into independent ventures. This could be done in a for profit setup inside the CoEs with enough autonomy for execution. For this close linkage be built with Industry accelerators and VC/PE funding ecosystems.
c. **Training and Consulting -** Helping Industries & Govt. learn how to innovate their processes and leverage AI strategically in their efforts, while increasing the base of AI engineers by offering open source courses for faster adoption

d. **Policy Guidance and help in formulation -** Policy creation for rapid and just adoption of AI across various stakeholders, while minimising long term risks working closely with Regulators, Govt. and Industry together

e. **Databank creation across strategic areas of focus -** Aggregating Data banks across verticals from Govt., Industry for offering data as a service for bootstrapping AI applications.

3.3.3 HRD and Skill Development

Table 3.3 shows the details of the HRD and skill development pertaining to the DAPT with respect to the schemes of the Govt. of India.

Table 3.3: HRD and Skill Development Pertaining to DAPT

HRD & Skill Development	1. CHANAKYA Schemes for UG courses (i) Graduate Internships (ii) Development Fund (For Projects done under Graduate Internships) (iii)CPS Infrastructure development fund
	2. CHANAKYA Schemes for PG courses (i) Post Graduate Fellowships (ii) Development Fund (For Projects done under PG Fellowships) (iii)CPS Infrastructure development fund
	3. CHANAKYA-DF (CHANAKYA Doctoral Fellowships)
	4. CHANAKYA-PDF (CHANAKYA Post-Doctoral Fellowships)
	5. CHANAKYA-Faculty Fellowship
	6. CHANAKYA-Chair Professor
	7. DAPT- PSDW (Professional Skill Development Workshop)
	8. DAPT-Upgrading PG Programme
	9. DAPT-Advanced Skill Training School (ASTS)

3.3.4 Innovation, Entrepreneurship & Start-ups

The Innovation, Entrepreneurship & Start-ups details under DAPT at IIT (BHU) are in Table 3.4.

Table 3.4: Innovation, Entrepreneurship & Start-ups

Innovation, Entrepreneurship & Start-ups	1. DAPT-GCC - Grand Challenges and Competitions
	2. DAPT-PRomotion and Acceleration of Young and Aspiring technology entrepreneurs (DAPT-PRAYAS)
	3. DAPT-Enterpreneur In Residence (DAPT-EIR)
	4. DAPT- Start-up
	5. DAPT-Technology Business Incubator (TBI)
	6. DAPT-Dedicated Innovation Accelerator (DIAL)
	7. DAPT-Seed Support System (DAPT-SSS)
	8. DAPT-SISE (Strategic Information Services for Entrepreneurship)

3.3.5 International collaborations

Table 3.5 describes the various activities to be undertaken as a part of international collaborations under NM-DAPT.

Table 3.5: International Collaboration Activities

International Collaborations	International Joint UG/PG degree programs
	International travel/ exchange programmes
	International workshops/conferences/meetings

Chapter-4

Mission Finance

4.1 Finance

The source of financing for the schemes is through Department of Science & Technology, Govt. of India under NM-ICPS as a TIH. No external sources are intended during first FIVE years of TIH establishment. This TIH will be a Section-8 Company and post FIVE years, its business will make it self-sustainable.

Cost Estimates

The cost estimates are arrived based on discussions of the committee members as well as experts and stakeholders. The CoE estimates for the scheme duration: both year-wise, component-wise segregated into recurring and non-recurring expenses.

Table 4.1: Budget Summary

Total Recurring Cost	57.644 Crores
Total Non-Recurring Cost	61.28 Crores
Total Cost (Recurring + Non-Recurring)	118.924 Crores

Table 4.2: Year wise Budget Estimate

Budget Head	1 Year	2 Year	3 Year	4 Year	5 Year	Total (Crores)
Manpower	1.825	1.825	1.848	1.848	1.848	**9.194**
Travel	0.250	0.350	0.500	0.500	0.500	**2.100**
Technology Development	0.300	1.300	3.300	4.300	1.300	**10.500**
HRD and Skill Development	4.45	4.75	4.75	4.45	4.45	**22.85**
Innovation, Enterpreneurship and Startup Ecosystem	0.5	2.00	2.00	3.000	1.500	**9.000**
International Collaboration	0.000	1.000	1.000	1.000	1.000	**4.000**
Equipment	7.000	35.250	19.030	0.000	0.000	**61.28**
Grand Total	**14.325**	**46.475**	**32.428**	**15.098**	**10.598**	**118.924**

Table 4.3: Manpower Budget Summary

Designation	Year-1	Year-2	Year-3	Year-4	Year-5	Total (INR)
JRF/SRF (Chanakya Doctoral Fellows) No. of Person: 50 Budget Breakup: JRF 31000 + 16% HRA SRF 35000+ 16% HRA Estimating 02 JRF/SRF in each of the 25 projects inter-disciplinary projects and the scholar may be taken from other disciplines	1,798,000	1,798,000	2,030,000	2,030,000	2,030,000	**9,686,000**

Network Manager No. of Person: 1 Budget Breakup: 96000 + 16% HRA He will handle the 5G-IOT network and configure protocols for application level, sensor nodes and gadgets	13,36,320	13,36,320	13,36,320	13,36,320	13,36,320	**66,81,600**
Chief Executive Officer No. of Person: 1 Budget Breakup: 1.5 lacs Overall monitoring and execution of the programm	18,00,000	18,00,000	18,00,000	18,00,000	18,00,000	**90,00,000**
Project Manager No. of Person: 2 Budget Breakup: 96000+ 16% HRA Estimating that about 25 concurrent projects will run and 02 project managers will ensure tidy control and administration of activities in TIH	26,72,640	26,72,640	26,72,640	26,72,640	26,72,640	**1,33,63,200**
Research Associate/PDF No. of Person: 12 Budget Breakup: 47000+ 16% HRA Estimating that 25 concurrent projects will run and 1 RA/PDF can maximally handle 02 projects with good dedication	78,50,880	78,50,880	78,50,880	78,50,880	78,50,880	**3,92,54,400**
Skilled Staff (MTS) No. of Person: 06 Budget Breakup:19350/- Estimating that 25 projects will be administratively monitored and records will be maintained in the TIH office.	13,93,200	13,93,200	13,93,200	13,93,200	13,93,200	**69,66,000**
Unskilled Staff (MTS) No. of Person: 08 Budget Breakup:14610/- Estimating that 15-17 projects will require active field testing and other office paper movements will be required at TIH	14,02,560	14,02,560	14,02,560	14,02,560	14,02,560	**70,12,800**

Table 4.4: Travel Cost Details

Justification (Inland Travel)	Year-1	Year-2	Year-3	Year-4	Year-5	Total (INR)
The proposed TIH researchers will be collaborating and handholding of various collaborating research institutions and industry. Therefore, frequent movement of researchers for various tests and discussions will be strongly recommended.	25,00,000	35,00,000	50,00,000	50,00,000	50,00,000	**2,10,00,000**

Table 4.5: Technology Development

Justification	Year-1	Year-2	Year-3	Year-4	Year-5	Total (INR)
The proposed TIH will develop core facilities, techniques, technologies for real-time applications in IOT and CPS and real field testing on short and long terms will be carried out thoroughly to ensure the robustness of the products. Miscellaneous items, circuit housings, and on-boards systems will also be required during field trials. Various national and international patents and publications will also be supported.	0	1,00,00,000	3,00,00,000	4,00,00,000	1,00,00,000	**9,00,00,000**

Table 4.6 HRD and Skill Development

Justification	Year-1	Year-2	Year-3	Year-4	Year-5	Total (INR)
The proposed TIH researchers will be collaborating and handholding of various research institutions and industry. Therefore, frequent training of external researchers and engineers from corporate sectors and industry will also be carried out. Multiple textbooks, experiments, manuals product catalog will also be made for its use during various kinds of skill and Human Resource development. A series of brainstorming workshops, symposia, conferences, and summits will be also held	1,00,00,000	1,20,00,000	1,50,00,000	1,50,00,000	2,00,00,000	7,20,00,000

Table 4.7 Innovation, Entrepreneurship and Startup

Justification	Year-1	Year-2	Year-3	Year-4	Year-5	Total (INR)
Variety of innovative solutions, tools and gadgets for societal benefits will also be encouraged for production through providing support to entrepreneurship and by establishing start-up companies of the stakeholders of TIH at IIT(BHU). A business park will be established where competencies of entrepreneurs will be enhanced and financial and technical support will be extended to entrepreneurs in the form of fellowships guidance and by providing working space.	50,000,00	2,00,00,000	2,00,00,000	3,00,00,000	1,50,00,000	**9,00,00,000**

Table 4.8: International Collaboration Detail

Justification	Year1	Year-2	Year-3	Year-4	Year-5	Total (INR)
Key technologies in niche areas of DAPT will be pursued at various state of the art laboratories all across the globe. Wherever, necessary significant Bi-directional exchange of experts will be encouraged. Honorarium and other expenditures will be made as per SPARC/GIAN projects including contingency for minor purchases.	0	1,00,00,000	1,00,00,000	1,00,00,000	1,00,00,000	**4,00,00,000**

Table 4.9: Equipment Budget Detail

Generic Name Model No. (Make)/ Justification	Quantity	Spare time	Estimated Cost (INR)
US server Blade with Accelerator or eq. Required for creating 5G - IOT Lab	2	30%	**28,80,000**
Flexible Automation System with Integration of hardware and software with Digital Twin &Iotconnecti Generic (Generic) It is necessary for smart factory automation	1	30 %	**16,42,825**
Access Switch Nexus 9300 (Cisco) Required for creating 5G - IOT Industry Grade Network	4	30%	**58,40,000**
Core Router ASR 1000 Required for creating 5G - IOT Industry Grade Network	2	30 %	**1,16,80,000**
Intermediate Job Transfer Station Generic (Generic) It is necessary for smart factory automation	3	30 %	**11,95,281**
Cobot Based Robotics Assembly station generic (Siemens or equivalent) It is necessary for smart factory automation	1	30 %	**82,60,123**
Digital Product Design Suite, Simulation and validation Generic 10 user Required for product digitization and process digitization lab	1	30 %	**1,29,98,944**
FeliDAE platform with FPGA Required for creating 5G - IOT Lab	1	30 %	**1,44,00,000**
UCS server to host controller Required for creating 5G - IOT Lab	4	30%	**28,80,000**
Vision Inspection Station Generic (Generic) It is necessary for smart factory automation	1	30 %	**13,17,569**
MindSphere IoT Developer Platform with 3 years subscription Generic (Generic) Required in IOT Lab	1	30 %	**71,68,690**
NSO (Network Services Orchestrator) Required for creating 5G - IOT Lab	2	30%	**1,15,20,000**
Switch Nexus 9500 Required for creating 5G - IOT Industry Grade Network	2	30%	**1,16,80,000**
eLearning courseware for a period of 3 Years Generic 100 user (Generic) Necessary for training and teaching purposes	1	30%	**67,20,647**
Other network equipment (switches/routers/servers, etc..) Core 9K or better x 2 Distribution 9 Required for creating 5G - IOT Lab	1	30%	**2,60,00,000**
Perimeter Firewall FPR 4000 (Cisco) Required for creating 5G - IOT Industry Grade Network	2	30%	**1,75,20,000**
Datacenter Firewall FPR 4000 Required for creating 5G - IOT Industry Grade Network	2	30%	**1,75,20,000**
Network Behaviour Analysis Stealthwatch Required for creating 5G - IOT Industry Grade Network	1	30%	**73,00,000**
PTZ Camera Generic (Bosch/Sony) Required for creating 5G - IOT Industry Grade Network	5	30%	**9,12,500**
Drone Camera Generic (Bosch/Sony) Required for creating 5G - IOT Industry GradeNetwork	5	30%	**3,28,500**
Bullet Camera	5	30%	**4,38,000**

Generic Required for creating 5G - IOT Industry Grade Network			
Smart Lighting Generic (Application Partner) Required for creating 5G - IOT Industry GradeNetwork	1	30%	**1,09,50,000**
Industrial Switch Cisco (IE 4000) Required for creating 5G - IOT Industry Grade Network	10	30%	**10,95,000**
IOT Gateway Required for creating 5G - IOT Industry Grade Network	10	30%	**21,90,000**
Professional Display 55-70 Inch Generic (Samsung/LG) Required for creating 5G - IOT Industry Grade Network	5	30%	**14,60,000**
Desktop All in One Generic (Dell/HP/Lenovo) Required for creating 5G - IOT Industry Grade Network	5	30%	**14,60,000**
VC Unit with 23 inch screen Required for creating 5G - IOT Industry Grade Network	2	30%	**10,22,000**
VC Codec DX 80 Required for creating 5G - IOT Industry Grade Network	2	30%	**7,30,000**
VC Platform Software MCU (Required for creating 5G - IOT Industry Grade Network	1	30%	**73,00,000**
Setting up a Data Centre with suitable hardware and software	1	30%	**105197103**
Human f-MRI scanning facility, with spectroscopic mapping, and Brain Connectomics imaging facility Intera-Ingenia/Magnetom/Signa Necessary for IOT in medical healthcare setup	1	30%	**6,58,00,000**
10 kW Solar PV emulator Generic (Generic) Necessary for IOT based smart grid development	4	30%	**60,00,000**
Solar PV Panels and installation Generic (Generic) Necessary for IOT based smart grid development	4	30%	**72,00,000**
Hybrid inverters with wifi modules Generic (Generic) Necessary for IOT based smart grid development	6	30%	**36,00,000**
Smart meters with sim modules Generic (Generic) Necessary for IOT based smart grid development	20	30%	**4,00,000**
Power Analyzer Generic (Generic) Necessary for IOT based smart grid development	5	30%	**33,00,000**
Digital signal oscilloscope Generic (Generic) Necessary for IOT based smart grid development	5	30%	**60,00,000**
10 kW battery emulator with battery management system Generic (Generic) Necessary for IOT based smart grid development	2	30%	**95,00,000**
Differential voltage probes Generic (Generic) Necessary for IOT based smart grid development	20	30%	**38,00,000**
Current probes with power amplifier Generic (Generic) Necessary for IOT based smart grid development	15	30%	**38,70,000**
Zigbee based home automation gateway Generic (Generic) Necessary for IOT based smart grid development	10	30%	**70,000**
Data server, logger, routers Generic (Generic) Necessary for IOT based smart grid development	1	30%	**38,30,000**
Water Monitoring System CR310, SVR100 (Texas) Required for GIS based smart city planning	1	30%	**34,00,000**

Handheld Thermographic System VarioCAM HD research 980 with accessories Generic (Generic) Necessary for IOT based smart grid development	1	30%	**80,00,000**
Smart Street Lighting with sensor Generic (Generic) Necessary for IOT based smart grid development	100	30%	**10,00,000**
Indoor Reality Mapping System IR 1000T (Generic) Required for GIS based smart city planning	1	30%	**50,00,000**
Smart relays Generic (Generic) Necessary for IOT based smart grid development	20	30%	**7,00,000**
Arc GIS Server and ArcMap with extension and hardware Generic (IBM/HP/Dell or equivalent) Required for GIS based smart city planning	1	30%	**1,00,00,000**
Supervisory Control and Data Acquisition Generic (Generic) Necessary for IOT based smart grid development	1	30%	**95,75,000**
Cubo Central Controller, Lumos, Sires, Sirel, Zigbee, Tie line Generic (Generic) Necessary for IOT based smart grid development	40	30%	**16,00,000**
UAV with Parrot Sensor, Hyper Spectral Sensor, Thermal Camera and Laser System Generic (Generic) Required for GIS based smart city planning	1	30%	**1,00,00,000**
AC DC Grid Simulator Generic (Generic) Necessary for IOT based smart grid development	3	30%	**70,00,000**
Programmable AC-DC Electronic Load Generic (Generic) Necessary for IOT based smart grid development	8	30%	**75,00,000**
Smart Parking Generic (Application Partner) Required for creating 5G - IOT Industry Grade Network	1	30%	**1,16,00,000**
Nanoimprint Lithography Generic (Generic) Required for sensor fabrication facility	1	30%	**1,00,00,000**
Bio-3D Printer Generic (Generic) Required for sensor fabrication facility	1	30%	**100,00,000**
3 D Printer metallic and non-metallic	1	30%	**32000000**
High end computational facilities	1	30%	**15000000**
Upgradation of internet and LAN facilities in TIH centre	1	30%	**10000000**
Furnishing for TIH centre	1	30%	**13000000**
High end servers with processors and accessories	1	30%	**10000000**
Solar Simulator with IPCE Measurement Generic (Generic) Required for sensor fabrication facility	1	30%	**5000000**
Materials Printer Generic (Generic) Required for sensor fabrication facility	1	30%	**7500000**
Mini Twin Screw Extruder Generic (Generic) Required for sensor fabrication facility	1	30%	**10000000**

Note: It is important to mention that the Table 4.9 shows the list of equipment prepared to meet the desired aims/objectives of the five application areas identified by the IIT (BHU) for NM-

DAPT. However, an appropriate Apex Committee will be authorized to make amendments in the list of the equipment given in Table 4.9 in line with the requirements of the PI of accepted proposals.

Table 4.10: Mission Cost Analysis (in Rs. Crore)

Sub-Missions	Budget Head	1stYr	2ndYr	3rdYr	4thYr	5thYr	Total
Technology Development	Recurring	0.3	0.55	0.80	1.30	0.50	3.45
	Non-Recurring	0.0	0.75	2.50	3.00	0.80	7.05
	Sub-Total	0.3	1.30	3.30	4.30	1.30	10.50
HRD & Skill Development	Recurring	0.75	0.80	1.00	1.00	1.00	4.55
	Non-Recurring	0.25	0.40	0.50	0.50	1.00	2.65
	Sub-Total	1.00	1.20	1.50	1.50	2.00	7.20
Innovation, Entrepreneurship, and Start-ups Ecosystem	Recurring	0.50	2.00	1.50	2.50	1.25	7.75
	Non-Recurring	0.0	0.0	0.50	0.50	0.25	1.25
	Sub-Total	0.50	2.00	2.00	3.00	1.50	9.00
International collaborations	Recurring	0.0	0.50	0.50	0.50	0.50	2.00
	Non-Recurring	0.0	0.50	0.50	0.50	0.50	2.00
Total	Recurring	1.55	3.85	3.80	5.30	3.25	17.75
	Non-Recurring	0.25	1.65	4.00	4.50	2.55	12.95
Grand Total in Rs Crore		1.80	5.50	7.80	9.80	5.80	30.70

Table 4.11: Year-wise Physical and Financial Targets

Sub-Missions	Year 1		Year 2		Year 3		Year 4		Year 5		Total	
	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial
Technology Development	40	0.3	40	1.3	40	3.3	40	4.3	40	1.3	200	10.5
HRD & Skill Development	550	1.0	550	1.2	550	1.5	550	1.5	550	2.0	2750	7.2
Entrepreneurship, Innovation and Start-ups	20	0.5	20	2.0	20	2.0	20	3.0	20	1.5	100	9.0
International collaborations	25	0.0	25	0.5	25	0.5	25	0.5	25	0.5	125	2.0
Grand Total	635	1.8	635	5.0	635	7.3	635	9.3	635	5.3	3175	28.7

Table 4.12: Estimated Expenditure (Rs crore) for Sub Component HRD & Skill Development

Major Components		**Unit cost**	Targets						Budget					
			Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	**CHANAKYA Schemes for UG courses**													
	(i) Graduate Internships	0.01	10	10	10	10	10	50	0.1	0.1	0.1	0.1	0.1	**0.5**
	(ii)Development Fund (For Projects done under Graduate Internships)	0.01	5	5	5	5	5	25	0.05	0.05	0.05	0.05	0.05	**0.25**

	(iii) Infrastructure development fund	1	0.25	0.25	0.25	0.25	0.25	1.25	0.25	0.25	0.25	0.25	0.25	**1.25**
2	**CHANAKYA Schemes for PG courses**													
	(i) Post-Graduation Fellowships	0.03	10	10	10	10	10	50	0.3	0.3	0.3	0.3	0.3	**1.5**
	(ii) Development Fund (For Projects done under PG Fellowships)	0.02	2	2	2	2	2	10	0.04	0.04	0.04	0.04	0.04	**0.2**
	(iii) Infrastructure development fund	1	0.25	0.25	0.25	0.25	0.25	1.25	0.25	0.25	0.25	0.25	0.25	**1.25**
3	**CHANAKYA Doctoral Fellowships**	0.17	2	2	2	2	2	10	0.34	0.34	0.34	0.34	0.34	**1.7**
4	**CHANAKYA Post-Doctoral Fellowships**	0.32	1	1	1	1	1	5	0.32	0.32	0.32	0.32	0.32	**1.6**
5	**CHANAKYA-Faculty Fellowship**	0.3	1	1	1	1	1	5	0.3	0.3	0.3	0.3	0.3	**1.5**
6	**CHANAKYA-Chair Professor**	0.3	0	1	1	0	0	2	0	0.3	0.3	0	0	**0.6**
7	**Professional Skill Development Workshop**	0.05	10	10	10	10	10	50	0.5	0.5	0.5	0.5	0.5	**2.5**
8	**Upgrading PG Programme**	5	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	**5**
9	**Advanced Skill Training School**	0.1	10	10	10	10	10	50	1	1	1	1	1	**5**
Total in Rs Crore									**4.45**	**4.75**	**4.75**	**4.45**	**4.45**	**22.85**

Table 4.13: Estimated Expenditure (Rs crore) for Sub-Mission Innovation, Entrepreneurship& Start-ups ecosystem

Major Components		Targets						Budget					
		Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	DAPT-GCC - Grand Challenges and Competitions	0	2	2	1	0	5	0.0	0.25	0.25	0.10	0.0	0.60
2	DAPT-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (DAPT-PRAYAS	0	2	2	1	0	5	0.0	0.75	0.75	0.60	0.0	2.10
3	DAPT-Entrepreneur In	0	2	2	2	2	8	0.0	0.09	0.09	0.09	0.09	0.36

	Residence (DAPT-EIR)												
4	DAPT-Start-up	0	2	2	3	3	10	0.0	0.20	0.20	0.30	0.30	1.00
5	DAPT-Technology Business Incubator (TBI)	0	1	0	0	0	1	0.0	1.67	0.24	0.24	0.29	2.44
6	DAPT-Dedicated Innovation Accelerator (DAPT-DIAL)	0	2	2	2	2	8	0.0	0.20	0.20	0.30	0.30	1.00
7	DAPT-Seed Support System (DAPT-SSS)	0	2	2	2	2	8	0.0	0.20	0.20	0.30	0.30	1.00
8	DAPT-SISE (Strategic Information Services for Entrepreneurship)	0	1	1	1	2	5	0.0	0.10	0.10	0.10	0.20	0.50
Total		0	14	13	12	11	50	0.0	3.46	2.03	1.93	1.58	9.00

Table 4.14: Estimated Expenditure (Rs crore) for Sub-Mission International Collaborations

Major Component	Targets						Budget in Rs Crore					
	Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
International collaborations		2	2	3	3	10	0	0.5	0.5	1.0	1.0	3.0
Total												

Table 4.15: DAPT-PSDW (Professional Skill Development Workshop)

S No	Budget Head	Amount in Rs Lakhs
A.	Recurring	
	1. Contingencies	0.40
	2. Travel, honorarium to experts etc	2.50
	3. Miscellaneous	0.20
	Sub-Total	3.10
B.	Non-Recurring	
	1. Teaching Material	0.90
	2. Used case studies, Books, Journals, etc	1.00
	Sub-Total	1.90
	Grand Total	5.00

Table 4.16: CHANAKYA- DAPT-Advanced Skill Training Institute

S No	Budget Head	Amount in Rs Lakhs		
		Year-1	Year-2	Total
A.	Recurring			
	1. Contingencies	0.50	0.50	1.00
	2. Travel, honorarium to experts, etc.	2.00	2.00	4.00
	3. Miscellaneous	1.00	1.00	2.00
	Sub-Total	3.50	3.50	7.00
B.	Non-Recurring			
	1. Equipment	2.00	0.00	2.00
	2. Teaching Material	0.30	0.30	0.60
	3. Used case studies, Books, Journals, etc.	0.20	0.20	0.40
	Sub-Total	2.50	0.50	3.00
C.	Capital	0.00	0.00	
	Grand Total	6.00	4.00	10.00

Table 4.17: DAPT-GCC - Grand Challenges and Competitions

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	I. All India Competitions (Operating Costs for 1 GCC)	
	1. Human Resources	5.00
	2. Travel, honorarium to experts, etc.	10.00
	3. Miscellaneous	2.00
	4. Marketing, promotion and publicity	3.00
	5. Networking and training programmes	2.50
	6. Other administrative expenses including consumables, printing, publications, books, journals, etc.	5.00
	II. Awards	
	1. Reward @ Rs 0.50 lakhs per winner for 5 ideas	2.50
	Sub-Total	30.00
B.	**Non-Recurring**	
	Prototyping Grant/ Seed Fund @ Rs 5.00 Lakhs each for 5 winners	25.00
	Sub-Total	25.00
C.	**Capital**	
	1. Competitions location specific arrangements like furniture, tables, chairs, dash boards, product development and demonstration arrangements etc	5.00
	Sub-Total	5.00
	Grand Total	60.00

Table 4.18: DAPT-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (DAPT-PRAYAS)

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	1. Prototyping Grant/ Seed Fund @ Rs 2.00 Lakhs each for 5 ideas	10.00
	2. Travel, honorarium to experts, etc.	2.00
	3. Miscellaneous	1.00
	4. Other administrative expenses including consumables, printing, publications, books, journals, etc.	2.00
	Sub-Total	15.00
B.	**Non-Recurring**	
	1. Prototyping Grant/ Seed Fund @ Rs 8.00 Lakhs each for 5 ideas Raw material, Spare parts, consumables, etc.	40.00

	2. Fabrication/Synthesis charges of working model development or process that includes design engineering/Consultancy/Testing/ Experts costs, etc. @1 Lakh each	5.00
	Sub-Total	45.00
C.	**Capital**	
	1. Establishment of PRAYAS Center, Fabrication LAB, location specific arrangements like furniture, tables, chairs, dash boards, product development and demonstration arrangements etc	100.00
	2. Operation and maintenance of Fab lab @ Rs 10.00 lakhs per year for 5 years	50.00
	Sub-Total	150.00
	Grand Total	210.00

DAPT-Entrepreneur In Residence (DAPT-EIR): A grant of maximum Rs. 30,000 per month for a period of 12 months. The total estimated cost per unit is Rs 3.60 Lakhs under recurring.

DAPT-Start-up: A onetime grant of Rs 10.00 Lakhs to each selected student start-up. The total estimated cost per unit is Rs 10.00 Lakhs under recurring.

Table 4.19: DAPT-TBI

Budget Head	**ESTIMATED COST IN CRORE**					
	1st Yr	**2nd Yr**	**3rd Yr**	**4th Yr**	**5th Yr**	**Total**
Recurring						
1. Human Resources**(Core Management Team /Mentors and Tech Support Persons /Business Development Professionals)	0.0	0.05	0.05	0.05	0.05	0.20
2. Travel (@ Rs. 40,000 pm)	0.0	0.0	0.0	0.0	0.0	0.0*
3. Utility and maintenance	0.0	0.02	0.02	0.02	0.02	0.08
4. Marketing, networking & publicity	0.0	0.05	0.05	0.05	0.10	0.25
5. Training Programmes, Events, and Start-up-Resonators	0.0	0.05	0.05	0.05	0.05	0.20
6. Other Administrative Expenses including consumables, printing, publications, books, journals, etc.	0.0	0.02	0.02	0.02	0.02	0.08
7. Miscellaneous and Contingencies	0.0	0.05	0.05	0.05	0.05	0.20
Sub-Total	**0.0**	**0.24**	**0.24**	**0.24**	**0.29**	**1.01**
Non-Recurring						
1. D&D Rooms (Dies & Designs, FAB lab)	0.0	0.20	0.0	0.0	0.0	0.20
2. Office Equipment including state-of-the art communication network, Video Conferencing Facilities	0.0	0.05	0.0	0.0	0.0	0.05
3. Contingencies for non-recurring expenditure and other items	0.0	0.10	0.0	0.0	0.0	0.10
Sub-Total	0.0	0.35	0.0	0.0	0.0	0.35
Capital	0.0	0.0	0.0	0.0	0.0	0.0
1. Renovation/furnishing of space for DAPT-TBI ; (20,000 sf ; @ 600 psf);(Furniture / Test Benches / Installations; Incubation Cubicles	0.0	0.78	0.0	0.0	0.0	0.78

and Spaces /Interaction Centers) excluding the cost of land & building						
2. Thrust/application Area Equipment (Equipment /Machineries; Clean Rooms / Test Rigs / IT Systems; Instruments/Tools & Dies/Measuring Devices, etc)	0.0	0.30	0.0	0.0	0.0	
Sub-Total	**0.0**	**1.08**	0.0	0.0	0.0	**0.30**
Grand Total	**0.0**	**1.67**	**0.24**	**0.24**	**0.29**	**2.44**

*Will be met out of the travel grant of the Sub-Missions

F. DAPT- Dedicated Innovation AcceLerators (DIAL) The budget includes Human resource, logistics, travel, mentoring, infrastructure, training etc. The overall budget for running accelerators shall be Rs 1.5 crore per year with participation of 10-15 start-ups. Rs 1.00 crore as soft loan and Rs.2.00 lakh per technology as project handling charges, as grant to DIAL. The total estimated cost per unit is maximum Rs 2.00 crore under recurring.

G. DAPT-Seed Support System (DAPT-SSS): Given to eligible TBI's under recurring Head with a maximum cap of Rs 10.00 crore. However, the support should be utilised in 2-3 years. It is given as investment or debt to incubate with a maximum support of Rs 1.00 crore. The total estimated cost per unit is Rs 10.00 crore under recurring.

Table 4.20: Manpower

Table **Budget Head**	**1 Year**	**2 Year**	**3 Year**	**4 Year**	**5 Year**	**Total (Crores)**
Manpower	4.702	4.702	5.120	5.120	5.120	**24.763**

Table 4.21: Travel

Budget Head	**1 Year**	**2 Year**	**3 Year**	**4 Year**	**5 Year**	**Total (Crores)**
Travel	0.250	0.350	0.500	0.500	0.500	**2.100**

Table 4.22: Equipment

Budget Head	**1 Year**	**2 Year**	**3 Year**	**4 Year**	**5 Year**	**Total (Crores)**
Equipment	7.00	26.000	19.030	7.000	0.000	**59.030**

Note: The TIH, IIT (BHU) will establish the bye-laws under the umbrella of Govt. of India, Grants-In Aid rules for running projects under it. All the projects funded by TIH, IIT (BHU) will be governed by the Bye-Laws of TIH, IIT (BHU).

4.2 Time Frame

Implementation of the proposal will be done as per the following timeline.

Sl no.	***Activity/Milestone***	***1st year***				***2nd year***				***3rd year***				**4th Year**				**5th Year**			
		Q1	***Q2***	***Q3***	***Q4***	***Q1***	***Q2***	***Q3***	***Q4***	***Q1***	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
A1	*Data collection, Literature review, and Preliminary System design*																				
A2	*Simulation and paper design of planned prototype*																				
A3	*Laboratory prototype design and development*																				
A4	*Expert Driven New Knowledge Generation /Discovery* ***(TRL5)***																				
A5	*Development of products/ prototypes from existing Knowledge (By experts or teams)* ***(TRL6)***																				
A4	*Technology /product delivery in specific sectors* ***(TRL7)***																				
A5	Yearly review of progress																				
A6	*Mid Term Review*																				
A8	Preparation and Publication of final progress reports**																				
***Draft completion report for review (3 month prior to date of completion)*																					

In addition, the centre also acts as a mini project funding and monitoring agency. In order to administer the proposals from various agencies, following activities and their respective timelines would be followed.

	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
Activities	Q1	Q 2	Q3	Q4	Q 1	Q 2	Q3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Establishment of Project Unit																				
Preparing Guidelines																				
Calling for proposals																				
Assigning/sanctioning projects																				
Review of Schemes																				

Yearly review of progress																				
Mid Term Review																				
Preparation and Publication of progress reports																				

4.3 Benefit Cost Analysis

The developed technology benefits to consumers from the practical application of a research effort, e.g., reduction of Green House Gases (GHG) and air pollutant emissions; improved energy efficiency; reduction of vulnerability, exposure to natural hazards; improved health conditions, better user-friendly solutions, and improved quality of life. Human resource and skill development, start-up ecosystem and international collaboration comes under the ambit of the developed technology for the proposed plan. Against this backdrop, a comprehensive development of the physical infrastructure in terms of building of smart homes and cities would be a final outcome of this proposal which will attract investment to the cities setting a momentum for growth and development of our country. Thus, there would be tangible and qualitative pay back of the cost invested in this plan of development of smart homes and cities. This wing of TIH will develop intelligent networking and communication backbone for all the five sub areas under this TIH. Primary focus of the developed solutions and platforms will be to harness existing open source and produce sharable knowledge to leverage the compliance met by other existing and upcoming hardware and software solutions.

Crowd sourced platforms are also in vogue and provide huge opportunity to create innovative hardware and software stack and they may be commercialised beyond certain levels providing huge opportunities to create disruptive technologies the way Adruino, Raspberry Pi, Begalbone and many other platforms have changed the world scenario. With this mission, India will also get opportunities to create its innovative hardware and software sets to suite to stringent requirements of Industry 4.0 compatible solutions.

State-of-the-art technology development will also provide huge opportunity to establish entrepreneurship and start-up ecosystem. Such technologies will be scaled up to TRL-7 levels from scratch and will pave the way for ubiquitous application development. India being a developing country, innovative application solutions will also help create disruptive platforms for smart city verticals and prototypes which can further be scaled up to national and global levels. Whole new sets of standards and technologies are being developed for creating backbone networks to support Smart IoT and Intelligent CPS, and this mission will also give us huge opportunities to contribute and to develop new International standards like under IEEE,

3GPP and alike. Indian technologies will be forerunner, in global markets and we will be able to generate skilled manpower as well. Since this program is a scheme aimed towards betterment of social benefits diffusing the population as a whole (as Health and Wellbeing) it may not always be possible to measure the social gain incurred in terms of dollar profits. According to societal sector economic practice, we shall estimate the cost-benefit analysis in terms of the standard International Unit (I.U.) of health benefit, namely the DALY index (Disability Adjusted Life Years) which assesses the extra benefit due to a medical intervention that lessens the amount and duration of disability caused by a target disease. Cost benefit analysis (CBA) is a systematic process for calculating and comparing the benefits and costs of a project; the analysis requires factoring in all the costs and all the benefits and their proper quantification. The difference between the costs involved and the benefits delivered indicates whether the planned action on the project is advisable. A government invests in order to realise economic, social, environmental and cultural benefits for the community it represents. As such, the justification for public investment in R&D warrants public scrutiny and review as with all other areas of public decision making. A closer look points out to CBA being grounded in welfare economics; its application to traditional infrastructures, such as transport, water, energy is firmly established. The main categories of costs associated relate to the present value of capital, labour cost, other operating costs, such as materials, energy, communication, maintenance, etc., negative externalities, like air pollution or noise during construction and operations, and decommissioning. However, the use of CBA to evaluate R&D activities gets hindered by the intangible nature and the uncertainty associated to the achievement of research results. R&D activities are similar to other projects when it comes to investment but are unique when it comes to the benefit side of the projects. While for applied research, development and innovation most benefits accrue to direct and indirect users (firms, consumers, researchers and students) for fundamental research it is usually impossible to identify who will be the ultimate beneficiaries of a discovery. Further, R&D projects are also peculiar in a way that some producers of services are also their beneficiaries. Scientists produce knowledge, but are also users of such knowledge. The process is embodied in the production of knowledge outputs (i.e. technical reports, preprints, working papers, articles in scientific journals and research monographs) and their degree of influence on the scientific community in form of citations. Likewise, students and young scientists who spend a period working on projects are likely to earn higher human capital relative to their peers. The socio-economic value of this benefit can be the expected incremental lifelong salary earned by such individuals over their entire careers. It is important

to note, however, between the value of knowledge outputs (publications) and the value of knowledge per se embodied in scientific publications. The former is usually predictable, while the latter is often immeasurable. Also, the technology developed out of R&D efforts may not always see light of the day as its fate depends on market environment, cost effectiveness, competing technologies, cheaper imported products and host of other factors.

If successful, benefits of technology to consumers may also derive from the practical application of a research effort (e.g. reduction of Green House Gases (GHG) and air pollutant emissions; improved energy efficiency; reduction of vulnerability and exposure to natural hazards; improved health conditions, or simply lower production cost and sale price, etc.) and may not always be envisaged or visible upfront. In most cases, there is a potential but largely unknown future use-benefit; while it is conceptually important to acknowledge its role; classical cost-benefit analysis methods are often unable to quantitatively determine it, even if research on the topic is ongoing. It seldom happens that an evaluator of research is confident of being able to make predictions on the economic value of applications of fundamental research. Experience gathered over time suggests that most important outcomes of R&D investment- like new knowledge, skills and experience, are intangible and unquantifiable, their benefits may not be realised for some years and their impact may be felt in entirely unrelated areas. Against this backdrop, there have been efforts to do cost-benefit analyses of R&D activities but there is no established method developed yet; more so, for a Mission which also has human resource development, start-up ecosystem and international collaboration in its ambit.

4.4 Risk Analysis

Section-8 companies are pillars to societal benefits especially because they are non-profit in nature and core academicians and researchers lead technology and product development towards assured adoption of such technologies at a high degree of industrial relevance with minimalistic investments with justification and answerability. All risks are minutely observed and analysed and assured technology developments are taken-up to reduce risks. Commercial viability within the stipulated time frame is also another important factor to success of a project. Assuring that the projects are managed well with well deployed manpower is the key to assured success.

Dedicated teams with clear focus will be engaged to bring-out well timed products in a phased manner to ensure feasibility of the innovations are delivered to industry as a series of outcomes

and the credibility of the company is maintained over a long term. IPRs will be registered with proper openness for justified returns without loose ends.

In specific, following are the clear mechanisms that will ensure success of projects undertaken under various application areas.

(i) Though the implementation of technological innovation through R&D projects comes with challenges as they are prevalent with risks and uncertainties at every stage. However, an R&D project to improve an existing product or service has a better chance of success than one meant for a new product or service but the rewards are likely to be far lower. Taking a synoptic view and the risk aspect in stride, R&D is considered as an investment of the future. As the proposed work is a combination of innovation and improvement of existing products or services, it will have a very high rate of success.

(ii) Identification and assessment of the implementation risks would be undertaken, and reduction of the risks would be pursued in the undermentioned ways.

Legal / Contractual Risks: As customary in the clinical investigation field in the country, indemnification and insurance coverage for medical device trials should be taken during patient-based implementation of the projects.

Environmental Risks: Since no toxic chemicals would be produced, environmental risks would not be there.

Revenue Risks: Conventional assurance coverage would be considered, if recommended by the earlier mentioned Heath Technology & Management Cell (HT&MC) of the scheme.

Project Management Risks: Proper SWOT analysis of each target project should be undertaken, and ratified by each project's Monitoring sub-committee referred to above.

Regulatory Risks: A part-time tele-consultant on Medical Regulatory Affairs would be utilized to vet each project, he could be remunerated according to the number of projects he affirms.

Chapter 5

Mission Management

5.1. Management

This five-year project is very much important for our Nation and Society as covering Data Analytics and Predictive Technology in the five major areas as communication, power, heath & family welfare, transportation and defence. The stakeholders are government departments, industry, entrepreneurs, academic, national research labs, hospitals and defence sectors as the direct stakeholders and society as an indirect beneficiary of the technology. The mission follows the technology life cycle approach- idea to product by involving academia, research labs and industry. Always such big projects need continuous monitoring and evaluation. Therefore, it is proposed to create a **Mission Apex Council (MAC)** to guide the entire project and a **Mission Management Unit (MMU)** to oversee the implementation of the Mission as per the guidelines of the DST DPR.

5.1.1 Mission Apex Committee (MAC)

MAC will be the topmost executive body for DAPT, It would be empowered body to take key decision for the success of the Mission and be responsible for its periodic review and guidance. It would be chaired by the Director of the Institute and have two co-chairs. It will have representatives from the government departments, academia and industry. Eminent domain experts from research and academic institutions, from national as well as international agencies will also be members of MAC. The broad powers, functions and duties of the MAC (as per the DST DPR) would be as follows:

a) Assign roles and responsibilities to participating sub sectors i.e. five identified areas as sub CoEs.
b) To control overlaps, overlaps in outputs and suggest measures to minimize them.
c) Review, periodically (at least twice in a year), the technical and financial activities of the project and suggest suitable measures, as deemed fit, to meet the aims and objectives of the Mission.
d) Considering the latest trends and relevance, propose from time to time alterations and modifications to the deliverable to meet the aims and objectives of the Mission.

5.1.2 Mission Management Unit (MMU)

The implementation of the Mission will be done by a **Mission Management Unit (MMU)** created for the purpose as per the DST DPR. It will plan, appraise, approve, release funds, implement, manage, operate, monitor and evaluate the project that will be clubbed into 5 broad Programmes. The MMU will be headed by the Director of the institute and will have Programme Directors as its part. The MAC will ensure that sufficient fund is made available

to the MMU so as to run the project, ensure participation of stake holding department, attract financial stakes of industry at appropriate maturity level of technology and create infrastructure/ mechanisms that have public benefit outcomes. The MMU headed by a Director will have administrative, financial independence for functional autonomy so as to realise the mission goals and objectives. As per the DST DPR the major functions of the MMU would be:

(i) To work as the nodal agency of the Government of India for DAPT Mission and to coordinate with all the stakeholders.

(ii) Selecting components and activities included in the Mission from time to time and preparing annual action plans.

(iii) Developing and fine tuning the final delivery contents, mechanisms and performance measurement criterion of each of the component/activity to be undertaken by the Mission.

(iv) Developing and finalizing the guidelines & terms and conditions of the grants and various other formats and documents needed for making requests to participate in the project activities, submitting periodic reports, funds utilization statements etc.

(v) Seeking proposals from individuals, institutions and other organizations for undertaking the various components and activities selected to be included in the Mission from time to time.

(vi) Assign the responsibility of the delivery to competent agencies within government (State & Central) and outside such as national institutes of higher learning, research organizations, service providers and others in the Mission ecosystem.

(vii) Monitoring all the aspects of the delivery of the Mission components and activities and ensuring the quality of delivery.

(viii) To ensure effective coordination with implementing agencies together with collection of information pertaining to implementation and progress.

(ix) Overseeing and Management of the project funds, preparation of budget statements, utilization and re-appropriation etc.

Funds provided by the Government of India in the Mission to the MMU will be (in the form of tied grant and) kept in a separate Fund. These funds will be utilized only for the purposes for which they have been given and subject to the conditions laid down by the MAC.

Under each of the 5 programmes the implementation of these programmes will be overseen by Programme Directors, who by being part of MMU will ensure synergy and cohesion among the components. The components will cover the complete spectrum of technology life cycle

stages on one hand, to addressing the development of human resource, skills, entrepreneurship and international linkages on the other.

5.1.2.1 Project Advisory and Monitoring Committees (PAMC)/ Working Groups (WG)

For effective monitoring of the schemes there will be PAMC/ WG. The members of the PAMC/ Working Group would be drawn from stakeholders, such as Government, academia, research institutions, end-users organizations and industry. The PAMC/ Working Group would meet at least thrice in a year. The broad powers, functions and duties of the Working Group would be as follows:

a) Working PAMC/ WG shall be the recommending Body of projects/ schemes under the DAPT, and be responsible for evaluation, monitoring the progress of those projects.
b) The PAMC/ WG shall have powers to recommend projects, purchases and expenses of all types within the technical and financial scope of the Mission.

5.1.2.2 Human Resources at MMU

The overall Mission will be spearheaded by Mission Director DAPT. In all the five sub areas of the DAPT mission, i.e., Telecommunications, Power, Defence Research and Development, Road Transport and Highways, Health & Family welfare, the major focuses will be on (i) Technology Development (R&D), (ii) HRD & Skill Development, (iii) Innovation, Entrepreneurship & Start-ups and (iv) International Collaborations programs. These areas will be looked after by each Sub area Coordinators. Implementation of the project will involve considerable amount of coordination with external agencies both national and international, it is suggested, therefore, to provide a domain Coordinator (Project PI) to each of the sub area coordinators. To take care of the very large number of stakeholders such as Students, Participants of the training programmes, Faculty Members etc. and to keep track of the information and documents received and sent out from the project, a pool of Technical Assistants. The Organization Structure is as given in **Table 5.1 and 5.2**

Table 5.1: Organization Structure

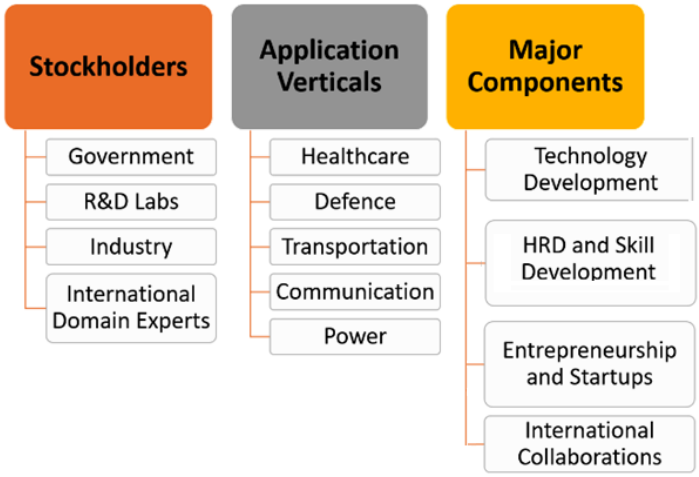


Table 5.2: Project Position

S. No.	Project Position	Numbers
1.	CEO/Mission Director	1
2.	Sub area Coordinators	5
3.	Project PI	One for each project
4.	Portfolio Managers (Technical Assistants)	5

No permanent or temporary post will be created by DAPT; the projected HR will be taken from the exiting faculty of the Institute or on contractual/ deputation basis only. No outsourcing of services or hiring of consultants is involved.

5.1.2.3 Cloud based technology platform for the Mission: Towards effective implementation of the Mission, third-party Cloud based technology platform will be created. This will have both computational and storage facility, accessible to all projects. It will also have centralized Web Portal for Mission Management which will provide collective information of running status of all the activities under the mission. Such portal will be a dynamic repository of information on all activities/components, resources and outputs, associated with the Mission. This will be continuously updated for monitoring the progress of the mission by the **Mission Management Unit (MMU).** The information will be used for periodic review of the Mission for seeking guidance from Mission Apex Committee (MAC)**.** Also, the information will be shared with all the stakeholders and participants in the mission to

ensure synergy. The funding to set up Web portal and its maintenance will be drawn from the MMU (it is taken from DPR of the DST).

5.2 Evaluation

Evaluation is key to improve the overall success of a proposal in accomplishment of its stated goals and objectives. Evaluation provides with a mechanism to document the implementation and progress and share with stake-holders. For evaluation to be effective whether of the project or any component thereof, it should be an integral part of the planning process. The proposed work would be evaluated as per the details given in Table 5.3.

Table 5.3 Evaluation Criterion

S No	Components	Activities	Output Indicator	Output Indicator	Outcomes
1	Technology Development	Number of Technologies (IP, Licensing, Patents, etc)	Fund Review	New Knowledge	Generation of Intellectual property Manpower of high order skills
		Technology Products	Fund Review	Proofs of Concept Prototypes	Generation of Intellectual property Closer interaction between industry & academia Prototyping facilities
		Publications, IPR and other intellectual activities	Fund Review	New technologies/ products/ solutions	Prototyping/ Translational research facilities Increased business in CPS
2	HRD and Skill Development	High end skill development	Funds Review	Advanced skill training schools established Self-employable technicians	Employable technicians Improved employability Improved installation, operation and maintenance services
		Graduate Fellowship	Funds Review	Graduates exposed to problem-solving	Trained Professionals
		Post Graduate Fellowships	Funds Review	Post-Graduates exposed to problem-solving	Trained Professionals and Problem-solving oriented education
		Doctoral Fellowships	Funds Review	Post-Graduates exposed to problem-solving	IP/ Technology generation Pool of trained professionals
		Post-Doctoral Fellowships	Funds Review	Young professionals with advanced knowledge of smart grid	IP/ Technology generation Pool of trained professionals with advanced knowledge

		Faculty Fellowships	Funds Review	Faculty with advanced exposure to Power Technology	IP/ Technology generation Mentors for UG, PG and Doctoral students
		Chair Professors	Funds Review	Specialist in Power Technology	IP/ Technology generationMentors for UG, PG and Doctoral students Improved ecosystem for teaching and research New educational material
3	Entrepreneurship and start-ups	Grand Challenges and Competitions	Funds Review	Ideas/ concepts/ challenges Prototypes	Start-ups New Smart Grid application areas
		Promotion of young and aspiring entrepreneurs	Funds Review	Young Entrepreneur	Employment generation Increased business
		Entrepreneur in residence	Funds Review	Entrepreneurs New ventures	Increased no. of start-ups Commercialized technologies Employment generation Increased business
		Start-ups and spin off companies	Funds Review	New ventures Entrepreneurs	Increased no. of student start-ups, Commercialized technologies, Employment generation Higher start-up success rate
		Technology Business Incubator	Funds Review	New ventures Entrepreneurs	Commercialization of technologies New technology/ knowledge/ innovation-based start-ups
		Seed support system	Funds Review	Technology-based enterprises	Technology refinement and marketing support mechanisms, New technology/ knowledge/ innovation-based start-ups
		Dedicated Innovation Accelerator	Funds Review	Fast track commercialized technologies	Speedy commercialization of technologies, Increased prospects of commercialization of technologies
4	International Collaborations	International Joint UG/PG degree programs	Funds Review	Identification of areas for joint degree program	Joint UG/PG Degree Program
		International travel/ exchange programmes	Funds Review	Identification of research areas for collaboration	Adapting and implementing the newly gained knowledge and experience in Indian Ecosystem, Benefitting from

				New Knowledge and experience	experiences of collaborators Recognition in International community, Enrichment of Indian CPS Ecosystem
		International workshops/conferences/meetings	Funds Review	Identification conference/ workshop theme	Organizing International workshops/conferences/ meetings

5.3 Environmental Impact

The proposal aims to develop a technology for solar integrated smart grid for smart homes and cities, transportation, health, communication and defence related technologies so should not have any environmental impact. There are no new constructions, land acquisitions, dislocations and other environmental clearances are required. However, if in any research such clearance is required it will be taken before start of the work.

CONCLUSIONS

As the amount of knowledge grows, an assessment of state-of-the-art in any fields becomes challenging. The Technology Innovation Hub on National Mission on Data Analytics and Predictive Technologies (NM-DAPT) at IIT(BHU) is going to be a flagship project for the country. We will be able to mount this mission to huge success by harnessing our large and capable research base along with our esteemed stake-holders in the form of our alumni spread all across the world, leading as industrialists, CEOs, core researchers and academicians leading across all the sectors of industries and society. NM-DAPT will significantly enhance current search capabilities to support deep scientific queries, technology development and application. Keeping in view the fast growth of DAPT across the technological verticals, it is imperative to plan a firm yet strategic roadmap in this direction to obtain the benefits towards the overall development of the country.

The DPR on NM-DAPT has established the need for a National Mission to (i) strengthen the smart cities mission of the country and (ii) take steps to nurture the same, to leverage the unique advantageous position of the country's manpower in not only in the scientific research and development but in the business and industry as well. The identified five thrust/application areas under NM-DAPT; 1) Telecommunications, 2) Power, 3) Defence Research and Development, 4) Road Transport and Highways, 5) Health and Family Welfare will cover the socio, economical, infrastructural, and defence development of the country. The strategy developed for the Mission and the programmes/ projects proposed under it have to be implemented in five years. The sub-missions under the main mission includes (i) Technology Development, (ii) HRD & Skill Development, (iii) Innovation, Entrepreneurship & Start-up ecosystem and (iv) International Collaboration.

The identified technologies, evaluation parameters, mission strategies, monitoring mechanism, deliverables, and self-sustainable approach of NM-DAPT have been delineated in this DPR. NM-DAPT objectives would be realized within the stipulated period with the timely investment and committed approach.

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