Telecom Regulatory Authority of India

Consultation Paper

on

Leveraging Artificial Intelligence and Big Data in Telecommunication Sector

New Delhi, India

(05 August 2022)

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Written comments on the consultation paper are invited from the stakeholders by September 16, 2022. Counter-comments, if any, may be submitted by September 30, 2022. The comments and counter-comments will be posted on TRAI's website: www.trai.gov.in.

The comments and counter-comments may be sent, preferably in the electronic form to, Shri Asit Kadayan, Advisor (QoS) Telecom Regulatory Authority of India, on email: advqos@trai.gov.in

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CONTENTS

Annexures

CHAPTER 1

BACKGROUND

1.1. Emerging Importance of Artificial Intelligence (AI) and Big Data (BD)

1.1.1. Artificial Intelligence (AI) and Big Data (BD) are the emerging technologies that are rapidly transforming today's world. Remarkable surge in AI capabilities have led to many innovations including autonomous vehicles, wearables to track health conditions, virtual assistants and face recognition systems. AI is contributing in development and revolutionization of each and every sector. As per report published by McKinsey & Company[1] AI has already been adopted in various industries such as High Tech Automotive and Assembly Lines, Telecom, Travel, Transport and Logistics, Consumer Packaged Goods, Retail, Electric Power and Natural Gas, Healthcare Systems and Services, Financial Services, Professional Services, Infrastructure Services and many more.

1.1.2. Like various other sectors, telecom sector is also undergoing digital transformation through adoption of AI and BD. These technologies have been deployed in telecom network for network operations, customer service provisioning, delivery management, and infrastructure operations of telecom companies. The adoption of AI and BD in telecom sector has improved network reliability and customer experience, optimized cost of operations, generated new revenue and taken strategic business decisions and much more. The information published on website, Guavus[2] states that AI with advanced analytics has saved 100 million USD in network Capital Expenditure (CAPEX) in first year. It further indicated that AI with advance analytics has reduced Mean time to repair (MTTR) and poor Quality of Experience (QoE) by 50% for Voice over Long-Term Evolution (VoLTE) subscribers, and also predicted 40% hardware

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[1]
https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Global%20AI%20Survey%20AI%20proves%20its%20worth%20but%20few%20scale%20impact/Global-AI-Survey-AI-proves-its-worth-but-few-scale-impact.pdf

[2] https://www.guavus.com/

failures prior to customer impact and reduced data storage by 90%. In future, these technologies would be a game-changer for achieving scalability and security demanded by 5G and the Internet of Things (IoT).

1.1.3. The pace of AI development has not been found consistent over the years since its inception sixty years ago[3]. The recent keen interest in AI may be attributed to technological advancements in internet, computation power, a number of data generating devices supported by the advent of technologies such as cloud computing and edge computing.

1.1.4. All these developments are further supported by advanced data analytics technologies and tools provided by BD which helps professionals to collect, process, clean and analyse growing volume of data. Common technologies and tools used to enable big data analytics processes include Hadoop, Spark, Predictive Analytics, Stream Analytics, Distributed Storage, and Data Virtualisation etc. Thus, with Big Data Analytics, AI can drive more value from the network data to train and test its models to initiate actions and decisions in the network. BD is a key element of AI. The Chapter 2 covers these aspects in detail.

1.1.5. The market for AI is already large and growing rapidly. In Feb 2021, the International Data Corporation (IDC)[4] predicted that by 2024, the market of AI is expected to break the $500 billion mark with a five-year Compound Annual Growth Rate (CAGR) of 17.5% and total revenues reaching an impressive $554.3 billion. Additionally, investment in AI and Machine Learning (ML) companies has increased dramatically. The Indian AI and analytics start-ups received $1,108 million in funding in 2021[5], the highest ever funding in seven years, with a year-over-year growth rate of 32.5%.

1.2. **AI Policy Landscape**

1.2.1. Though the benefits of AI are significant, it may sometimes have serious

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[3] https://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/
[4] https://www.idc.com/getdoc.jsp?containerId=prUS47482321
[5] https://analyticsindiamag.com/study-indian-ai-startup-funding-in-2021/

consequences such as privacy violations, discrimination and biased results. Probable risks from AI are attracting the attention of the regulators to examine and consider adequate measures to mitigate the same without losing the potential benefits. The probable risks are discussed in the later chapters. The section below highlights the strategies and initiatives taken by various countries to harness the potential of AI technologies, as well as address the associated risks.

1.2.2. **National Strategies in other jurisdictions (Countries)**

i. In the past few years, countries around the world have taken several initiatives to frame strategies to guide and foster the development of AI and mitigate the risks associated with it. The *Artificial Intelligence Index Report 2021[6]*, published by Stanford University has highlighted the initiatives taken by various countries in this regard. As per above report, countries like Canada, China, Japan, Finland, United Arab Emirates, began to formulate national and regional strategies in 2017. Thereafter, in 2018, many countries such as France, Germany, United Kingdom and European Union also has published their plans and strategies regarding adoption of AI and related subjects. As of now, many countries have prepared their strategic plans for the adoption of AI, and some are at the public consultation stage, as mentioned in table 1.1.

ii. Countries are focusing on key areas such as education, health, economy, transport etc. and are majorly focussing on subjects such as research and development, skilling and reskilling, development of standards, developing AI-related infrastructure, data hubs and ethics. Some of these initiatives will be discussed in detail in the following chapters.

iii. As per the information published on the websites and in the reports, most of the countries are working on the adoption of AI

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6 https://aiindex.stanford.edu/wp-content/uploads/2021/03/2021-AI-Index-Report_Master.pdf

from a national perspective. It is also worth noting that the responsibility to oversee AI development has either been given to existing ministries like education, health, communication, etc, or a new entity has been created particularly for this purpose. In countries like Canada, France, Germany, and others mentioned in table 1.1, existing ministries are part of strategic planning for AI initiatives. Whereas, in countries like the United Kingdom, Japan, Singapore, and Saudi Arabia, a separate entity such as an office/council/ department/authority, has been established for AI development.

Table 1.1:   List of countries with AI strategies

Country Name	AI Strategy	Responsible Organisation
Australia	Artificial Intelligence Roadmap / An AI Action Plan for all Australians	• Commonwealth Scientific and Industrial Research Organisation (CSIRO), • Data 61, and • the Australian government
Brazil	Brazilian Artificial Intelligence Strategy	Ministry of Science, Technology and Innovation (MCTI)
Canada	Pan Canadian AI Strategy	Canadian Institute for Advanced Research (CIFAR)
European Union	Coordinated Plan on Artificial Intelligence	European Commission
France	AI for Humanity: French Strategy for Artificial Intelligence	• Ministry for Higher Education, Research and Innovation; • Ministry of Economy and Finance; • Directorate General for Enterprises; • Public Health Ministry; • Ministry of the Armed Forces; • National Research Institute for Digital Sciences; Inter-ministerial Director of the Digital Technology and the Information and Communication System
Germany	AI Made in Germany	• Federal Ministry of Education and Research; • Federal Ministry for Economic Affairs and Energy; • Federal Ministry of Labour and Social Affairs

| Indonesia	National Strategy for the Development of Artificial Intelligence (StranasKA)	- Ministry of Research and Technology (Menristek), - National Research and Innovation Agency (BRIN), - Agency for the Assessment and Application of Technology (BPPT)
Japan	Artificial Intelligence Technology Strategy	Strategic Council for AI Technology
Russia	National Strategy for the Development of Artificial Intelligence	- Ministry of Digital Development, Communications and Mass Media; - Government of the Russian Federation
Saudi Arabia	National Strategy on Data and AI (NSDAI)	Saudi Data and Artificial Intelligence Authority (SDAIA)
Singapore	National Artificial Intelligence Strategy	Smart Nation and Digital Government Office (SNDGO)
South Korea	National Strategy for Artificial Intelligence	Ministry of Science, ICT and Future Planning (MSIP)
UK	Industrial Strategy: Artificial Intelligence Sector Deal	Office for Artificial Intelligence (OAI)
US	American AI Initiative	The White House

1.2.3. **National strategies and initiatives being taken in India**

India is catching up with the leading countries to harness the potentials of AI, BD. Many government projects and initiatives[7] at state and central level were undertaken in this direction, which got further push from NITI Aayog. A national strategy document on AI was published in 2018 by NITI Aayog. Ministries such as the Ministry of Commerce and Industry, Ministry of Electronics and Information Technology (MeitY), Department of Telecommunications (DoT) under Ministry of Communications, NITI Aayog under Ministry of Planning and many other departments in the Government have taken initiatives and are contributing towards the growth of AI in India. These initiatives cover

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[7] https://indiaai.gov.in/initiatives

aspects such as providing data for AI training, creating architecture for high computing infrastructure, boosting research and development, skilling-reskilling workforce, building centres for excellence, spreading awareness, and identifying principles and their implementation strategies for developing responsible AI system in the country. A brief description of all such initiatives taken by various ministries is listed in **Annexure II**. The timelines for the initiatives mentioned in the Annexure II is given below in figure 1.1:

Figure1.1:   **Initiatives taken by NITI Aayog and MeitY for Proliferation of AI in India**
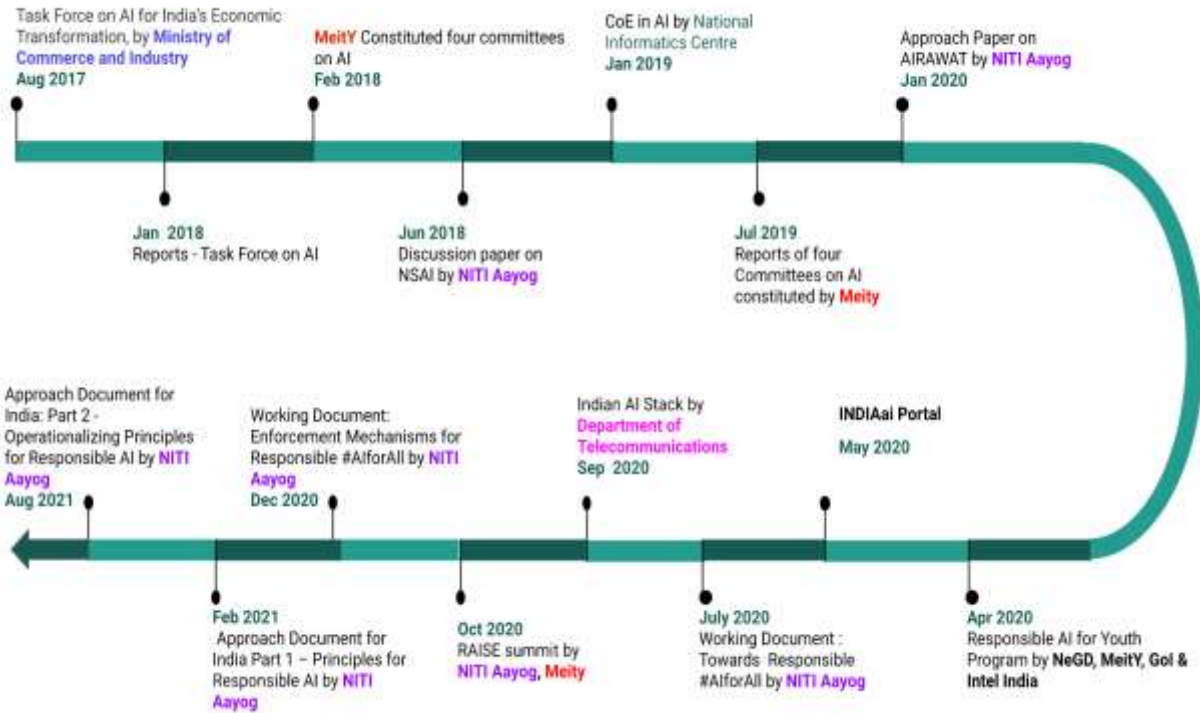
1.2.4.   Initiatives by International Regulators

Telecom sector regulators such as Infocomm Media Development Authority (IMDA) Singapore, Federal Communications Commission (FCC) of USA have taken further steps for leveraging AI technologies in their sectors. IMDA was an active partner in the national programme to catalyse, synergise and boost Singapore's AI capabilities. Also, in June 2019, IMDA released the Trusted Data Sharing Framework[8] to help

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[8] https://www.imda.gov.sg/infocomm-media-landscape/SGDigital/tech-pillars/Artificial-Intelligence

companies overcome challenges in addressing trust deficit between data providers and develop trusted data. Further, in May 2022[9], IMDA/PDPC launched A.I. Verify which is an AI Governance Testing Framework and Toolkit to demonstrate Responsible AI in an objective and verifiable manner. The FCC took cognizance of the impact of AI on the nation's network and formed a working group on AI (AIWG) to study the impact of AI in the telecom sector. The working group gave recommendations[10] on creation of a task force to address aspects of data governance. It also suggested that FCC should establish policies and approaches to ensure the safe use of AI.

1.2.5. **Initiatives taken by International Telecommunications Union (ITU)**

ITU has been actively involved in the quest for new technological solutions to address the issues on various aspects such as the technological needs of the future networks, natural disaster management, AI for Digital Agriculture and AI for health etc. The ITU created focus groups under study groups to augment the study group work programme by providing an alternative working environment for the quick development of specifications in their chosen areas. The task of these focus groups is to investigate and jump-start new directions in ITU-T standardization. A number of such focus groups are actively working on various subjects such as:

i. **Focus Group on Machine Learning (ML) for Future Networks including 5G (FG ML5G)**[11]**:** It was created by ITU-T Study Group 13 at its meeting in Geneva, 6-17 November 2017. The Focus Group drafted ten technical specifications for ML for future networks, including interfaces, network architectures, protocols, algorithms and data formats. FG ML5G was active from January 2018 until July 2020.

ii. **Focus Group on AI and IoT for Digital Agriculture (FG-**

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[9] https://www.imda.gov.sg/infocomm-media-landscape/SGDigital/tech-pillars/Artificial-Intelligence
[10] https://www.fcc.gov/sites/default/files/fcc_aiwg_2020_whitepaper_final.pdf
[11] https://www.itu.int/en/ITU-T/focusgroups/ml5g/Pages/default.aspx

AI4A)[12]**:** It was created to improve the management of agricultural production processes and achieve food security.

iii. **Focus Group on Technologies for Network 2030 (FG NET-2030)**[13]**:** It was created to study the capabilities of networks for the year 2030 and beyond.

iv. **Focus Group on AI for Natural Disaster Management (FG-AI4NDM)**[14]**:** It was created to explore the potential of AI in supporting data collection and handling, improving modelling, extracting complex patterns and gaining insights from a growing stream of geospatial data to enhance the preparedness for (and response to) natural disasters.

v. **ITU-T Focus Group on AI for autonomous and assisted driving (FG-AI4AD)**[15]: It was created to support standardisation activities of AI evaluation in autonomous and assisted driving.

vi. **ITU-T Focus Group on "Environmental Efficiency for Artificial Intelligence and other Emerging Technologies" (FG-AI4EE)**[16]**:** It was created to identify the standardization gaps related to the environmental performance of AI and other emerging technologies including automation, augmented reality, virtual reality, extended reality, smart manufacturing, industry 5.0, cloud or edge computing, nanotechnology and 5G among others.

1.2.6. **AI Policy Landscape in Telecom Sector**

i. Apart from the national strategies and general policies on AI, sector specific regulatory requirements are being worked out to address the challenges associated in adoption of AI. Sector specific requirements are also aligned in line with policies and strategies on AI at national level.

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[12] https://www.itu.int/en/ITU-T/focusgroups/ai4a/Pages/default.aspx
[13] https://www.itu.int/en/ITU-T/focusgroups/net2030/Pages/default.aspx
[14] https://www.itu.int/en/ITU-T/focusgroups/ai4ndm/Pages/default.aspx
[15] https://www.itu.int/en/ITU-T/focusgroups/ai4ad/Pages/default.aspx
[16] https://www.itu.int/en/ITU-T/focusgroups/ai4ee/Pages/default.aspx

ii.	In India, the National Digital Communications Policy[17] (NDCP), 2018 seeks unlocking of the transformative power of digital communications networks for achieving the goal of digital empowerment and improved well-being of the people of India. The efforts are being made to outline a set of goals, initiatives, strategies and intended policy outcomes. NDCP further, motivates towards harnessing the power of emerging digital technologies, including 5G, AI, Internet of Things (IoT), cloud and BD to catalyse the fourth industrial revolution. Thus, in order to create a roadmap for AI, emerging technology and its use in the communication sector, vide letter [**Refer Annexure I**] dated 6th June 2019, Department of Telecommunication (DoT) sought recommendation of TRAI on the provision no. 2.2(g) of NDCP-2018 i.e. *"Leveraging Artificial Intelligence and Big Data in a synchronised and effective manner to enhance the overall quality of service, spectrum management, network security and reliability"*.

## 1.3.	**Scope of Consultation Paper**

1.3.1.	The aspects of AI and BD referred by the DoT for seeking recommendations from TRAI mainly focusses on the telecom sector. However, there are many other sectors where telecom and Information and Communications Technology (ICT) sector can play an important role in building AI based capacity and capabilities. To understand such capabilities, a virtual conference on "Leveraging Artificial Intelligence (AI), Machine Learning (ML), and Big Data in the Telecom Sector" was organised by the TRAI on 5th and 6th of August 2020. Conference provided an opportunity to interact with the industry experts, telecom service providers and leading solution providers to understand AI and BD from telecom's perspective, learn about use cases of AI and BD in telecom sector and global view of network insights with AI and BD. It was also presented how future networks shall incorporate AI at various levels to make telecom networks as a cross-sectoral hub for flow of

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[17] https://dot.gov.in/sites/default/files/Final%20NDCP-2018_0.pdf

information. The next generation telecom network would offer services far beyond connectivity which include computational power, storage, and role in developing and running AI models. For leveraging AI and BD in the telecom sector and its support to other sectors for exploiting features of AI and BD, a re-look is required on existing provisions of the licenses and regulations in telecom sector. Further, it is required to explore new possibilities that might be useful for promotions and expansions of AI based systems in the respective sectors.

1.3.2.   Accordingly, the scope of the consultation paper is to seek comments from stakeholders on the aspects referred to by the DoT and also to seek comments on various other aspects where the telecom sector can play an important role to leverage AI and BD in other sectors.

1.4.   Structure of Consultation Paper

This consultation paper is composed of six chapters. Chapter 2 deliberates on the concepts of Artificial Intelligence (AI) and Big Data (BD). Chapter 3 discusses opportunities of AI and BD in the telecom sector, and also highlights telecom's role in leveraging AI and BD in other sectors for providing access to data, offering execution environment, providing a privacy preserving architecture, and developing a federated model to learn. Risks and concerns involved in adoption of AI and BD are also discussed. Chapter 4 discusses the key constraints in adoption of AI and BD in the telecom sector and in offering its capabilities to others. Chapter 5 deliberates on possible ways to accelerate adoption of AI and BD. Chapter 6 lists out issues for consultation.

CHAPTER 2

INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND BIG DATA

2.1.   **Artificial Intelligence (AI): Moving Beyond Automation**

2.1.1.   The automation and its progressive journey have seen a remarkable success in a short period of time. The automation is to perform tasks through predefined processes using tools without human intervention over a long period of time. Increasing production and improving performance are outcomes of automation. With advancements in technologies such as AI and BD, automation has evolved as an intelligent system capable of performing tasks by using knowledge and learnings acquired from its past experience. The figure 2.1 shown below illustrates how automation has moved towards intelligence with AI.

Figure 2.1:   Journey of AI from Automation
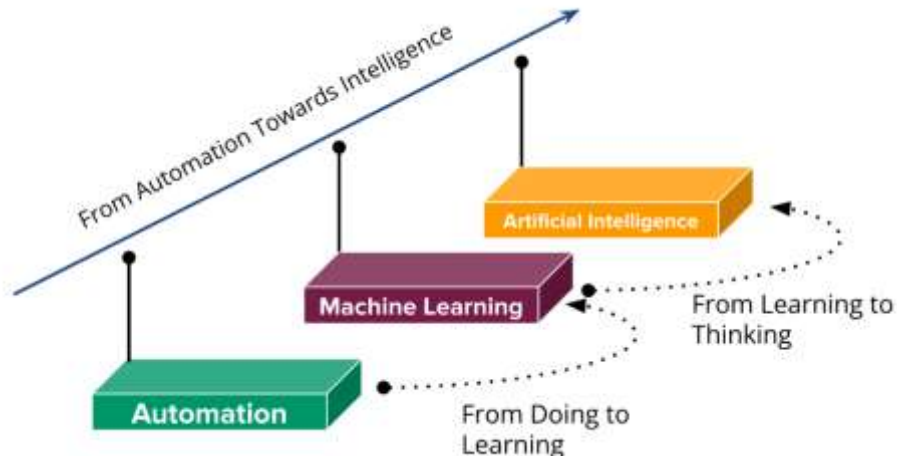
2.1.2.   Following example further explains how AI is the future of automation. Operations of call centres with sharing loads between agents and automated Interactive Voice Response System (IVRS) have improved accessibility, efficiency and capacity of call centres, in terms of volume of calls being handled and reduced response time to customers' queries. If the same automated system is enabled with AI, it addresses the concerns of customers by learning from past experiences. Further, the

system can be operated on 24*7 basis with enhanced capability and ability to think after learning. The AI provides cognitive ability to think and therefore helps in addressing complex issues with improved customer satisfactions.

2.1.3. The idea behind AI is to create machines which emulate human faculties of cognition, reasoning, analysis among others. A simple representation in figure 2.2 describes the concept of AI. The Virtual Assistants for example Tobi (Vodafone), Personalised Tariff Plans (Smart Recommendation Engine), Smart Cars (Google's self-driving car project to Tesla's "autopilot") and Self Organising Networks are a few areas where AI is being used.

Figure 2.2:   AI in a nutshell

2.1.4. Further, following paras describes the status and trends of AI[18]:

i.   **Trend of ML Algorithms:** In areas of speech recognition, computer vision, Natural Language Processing (NLP), deep learning algorithms bring more practicality than the classical machine learning algorithms. More deep learning algorithms are continuously being developed by academia and industry.

ii. **Trend of dataset:** AI public data sets are constantly being enriched and every industry is building its own AI data set which is driving the industrial development of data as a service.

iii. **Trend of Chips:** Although Central Processing Unit (CPU), Graphics Processing Unit (GPU) and Field Programmable Gate Arrays (FPGAs) are mainly used in AI, Application-Specific Integrated

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[18]https://www.itu.int/en/ITU-T/Workshops-and-Seminars/201903/Documents/Jun_Liao_Presentation.pdf

Circuit (ASIC) chips for Neural Network algorithms are also being launched. Brain-like chips such as Neuromorphic chips are still at the stage of research and development.

iv. **Trend of AI platforms:** Open-source AI frameworks such as Tensorflow, Pytorch, Azure etc have become the focus of AI layout for both academia and industry. Recent trend is towards developing AI capabilities and building an AI ecology.

v. **Trend of AI products:** Presently, AI products can cater to only a specific scenario in the field of speech, vision and motor action but intelligent products are being continuously developed to support more and more complex scenarios.

vi. **Trend of businesses:** Telecom operators are paying attention to scenario-driven applications in the medical industry, the financial industry, the retail industry, etc.

2.1.5. Similarly, AI also brings vast opportunities for telecom sector too. However, before leveraging AI, it is necessary to understand AI and its related terms to identify new opportunities for telecom sector. The following covers all these aspects in detail.

2.2. What is AI and how it works?

2.2.1. Over the years, there have been numerous attempts to define AI precisely. However, till date, there is no globally accepted definition of AI. Governments, regulatory agencies, international agencies, and other forums have adopted varying definitions depending on the context before them. John McCarthy[19], the father of AI, who coined the term in 1956, defines it as "*the science and engineering of making intelligent machines."* Following are some of the definitions of AI that have been adopted in different contexts.

i. **ETSI**[20] defines AI as "*a computerised system that uses cognition to*

[19] http://jmc.stanford.edu/artificial-intelligence/what-is-ai/index.html
[20] https://www.etsi.org/deliver/etsi_gr/ENI/001_099/004/01.01.01_60/gr_ENI004v010101p.pdf

understand information and solve problems".

ii. **ISO/IEC 2382-28 [i.7][21]** defines AI as *"an interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning".*

iii. **NITI Aayog** in its report[22] on the National AI Strategy defines AI as a constellation of technologies that enables machines to act with higher levels of intelligence and emulate the human capabilities of sense, comprehend and act while acknowledging the largely accepted definition of AI outlined by scientists such as John McCarthy, Alan Turing, and Marvin Minsky.

2.2.2. Globally, the solution providers and organisations categorise AI applications based on their capabilities and based on their functionalities. As per Industry practice[23] AI may be divided into following types based on the capabilities as shown in Figure 2.3:

Figure 2.3: Types of AI based on capabilities
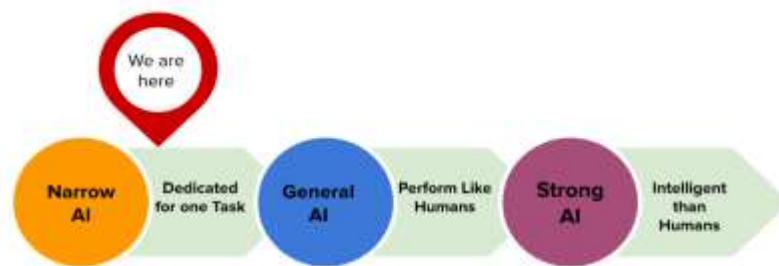
i. The **Weak AI**, also known as narrow AI, has limited functionality. IBM[24] considers self-driving cars and virtual assistants such Siri under the category of Weak AI. Weak AI has changed many aspects of business and our personal lifestyles by being able to solve or complete tasks much quicker or better than humans can.

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21 https://www.iso.org/obp/ui/#iso:std:iso-iec:2382:-28:ed-1:v1:en
22 https://niti.gov.in/writereaddata/files/document_publication/NationalStrategy-for-AI-Discussion-Paper.pdf
23 https://www.ibm.com/cloud/learn/strong-ai#toc-strong-ai--YaLcx8oG
24 https://www.ibm.com/cloud/learn/strong-ai

It has certainly been a transformative technology thus far.

ii. The **General AI** are those applications where machines emulate human capabilities and perform any task just like a human. Currently, there are no such example but the research and development are focused on achieving this technology.

iii. The **Strong AI** at this point may only be theoretical. It's when machines develop consciousness and decision-making on par (or better) than humans. When strong AI is achieved, the machines won't rely on human programming to be able to think or accomplish tasks. Additionally, machines with strong AI may be able to exhibit self-awareness and emotions. Ultimately, the goal with strong AI is a machine that has intelligence in true human form.

AI applications can also be classified based on the functionalities of AI systems. Depending on how a machine compares to humans in terms of versatility and performance, it can be a simple reactive machine that focuses only on current scenarios and reacts as per possible best action, or an intelligence exhibiting emotions capable of interacting socially like humans. The following are the types of AI-enabled machines based on their likeness to the human mind and behaviour.

i. **Reactive machines:** These are the simplest AI machines which can perform basic operations like object recognition, spam filter, etc. They merely react to the given input or scenarios and give output, during which no learning happens. The functionality of these machines is confined to one task only. For example, IBM chess program that beat Garry Kasparov in the 1990s.

ii. **Limited Memory Machines:** AI systems can use past experiences to inform future decisions. Limited memory machines have the capabilities of purely reactive machines, but is capable of learning from historical data to make decisions. For instance, an image recognition AI is trained using thousands of pictures and their

labels to teach it to name objects it scans. When an image is scanned by such an AI, it uses the training images as references to understand the contents of the image presented to it, and based on its "learning experience", it labels new images with increasing accuracy. Almost all present-day AI applications, from chatbots and virtual assistants to self-driving vehicles, are all driven by limited memory AI.

iii. **Theory of mind AI** is the AI system that can understand the entities. It interacts by discerning their needs, emotions, beliefs, and thought processes.

iv. **Self-aware AI**, which is self explanatorily, is an AI that has evolved to be so akin to the human brain that it has developed self-awareness. Creating this type of AI is and will always be the ultimate objective in all AI research and also a regulatory challenge.

2.2.3. **How does AI Work?**

i. Traditional programming methodology compelled programmers to use their own intelligence to write algorithms and create programs. These programs were then fed with data to generate desired outputs. However, recent advancements in technologies like AI enable machines to write their own programs with given data and desired outcomes. The figure 2.4 shows how AI is different from traditional programming.

Figure 2.4: Comparison between traditional programming and AI
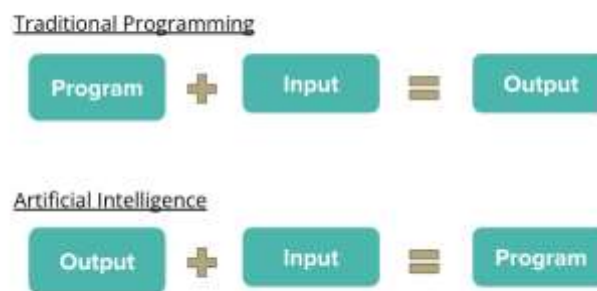
ii. The following paras describe the working of AI and the learning process of AI. To better understand the working of AI, a flowchart is shown in figure 2.5. The process of data handling in AI, is as follows: The historical data is divided into three parts: training data, validation data and testing data. The working of AI begins with model training. The model is trained on training data for a given set of parameters at this stage. This process produces a trained model and training evaluation data. The next step is to validate the model based on validation data. This stage also produces validation data results. Thereafter, validation data results are fed into parameter tuning to achieve the desired objective. The process continues till a final model for the desired objective is produced. At last, the final model is launched in the system to work upon the testing data.

Figure 2.5: Flowchart of various stages in AI modelling
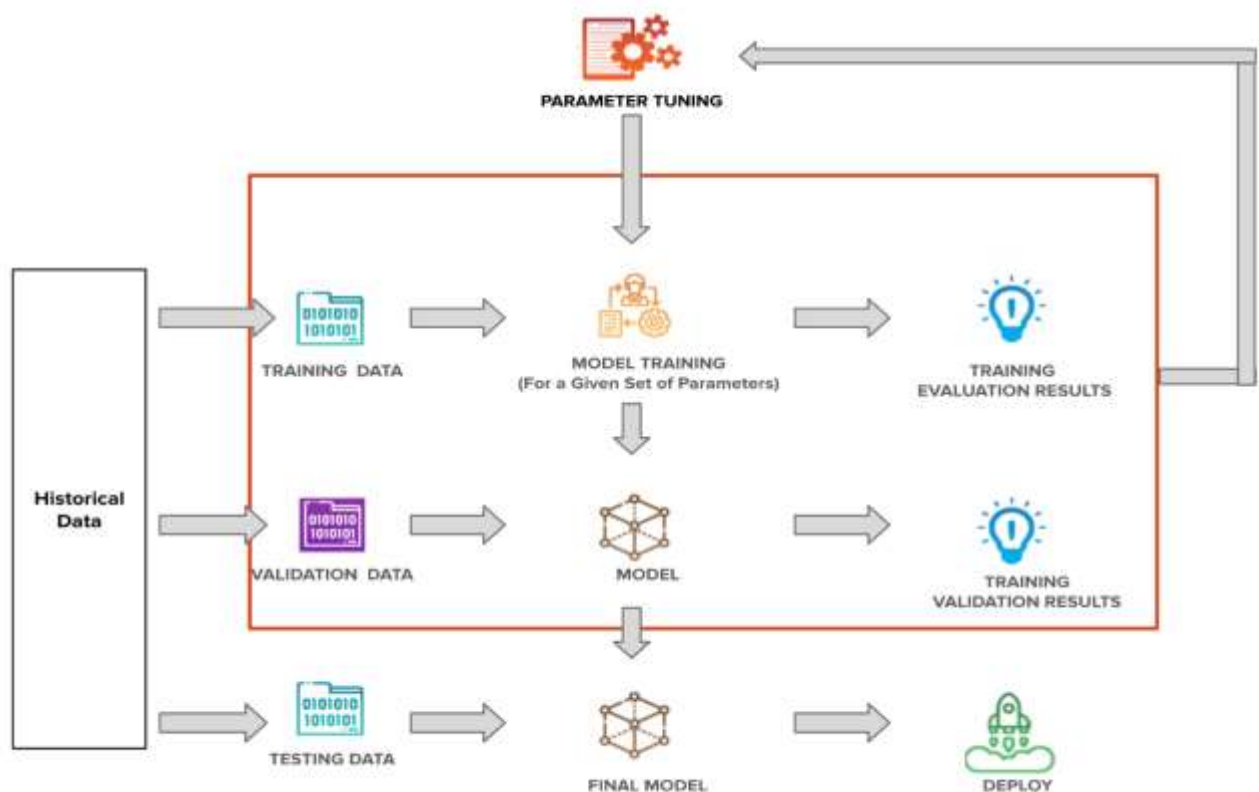
iii. In the above discussion, the training phase includes learning from data which makes the machines capable of understanding underlying hidden patterns in data. This learning process is termed Machine

Learning. **Machine learning**[25] is defined by ITU as, "*a process that enables computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed*". To gain knowledge, one can understand the process by considering the following modelling techniques used in machine learning:

a. In **Supervised Learning**, labelled data is used for training. Since the data is known, the learning is, therefore, supervised, i.e. directed into successful execution. The input data goes through the Machine Learning algorithm and is used to train the model. Once the model is trained based on the known data, one can use unknown data into the model and get a new response. Consider this use case where an autonomous car is employing a supervised learning model which has been trained to recognise various objects on the road, such as, pavement, humans, traffic lights, roads, sideways, cars, buildings etc. The car navigates effortlessly on the road, avoiding collisions. This is achieved through innumerable nuances of each object being used to train the ML model. Understanding the hidden characteristics of each object, the machine learns to identify and distinguish among them.

b. **Unsupervised Learning**, also known as unsupervised machine learning, refers to the use of artificial intelligence (AI) algorithms to identify patterns in data sets containing data points that are neither classified nor labelled. These algorithms discover hidden patterns or data groupings without the need for human intervention. Its ability to discover similarities and differences in information make it the ideal solution for exploratory data analysis, cross-selling strategies, customer segmentation, and image recognition.

c. **Reinforcement Learning** is another method where the requirement of supervisor or labelled data is not required, rather

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[25] https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.3172-201906-I!!PDF-E&type=items

training happens in the form of interaction with the environment and observing its response. This method is similar to how a dog learns to fetch a wooden stick. Dogs are rewarded with a biscuit on successful completion of tasks but may not get one when doing otherwise.

iv. The figure 2.6 given below highlights what types of ML techniques may be used in which type of applications in telecom:

Figure 2.6: Machine Learning Classifications[26]
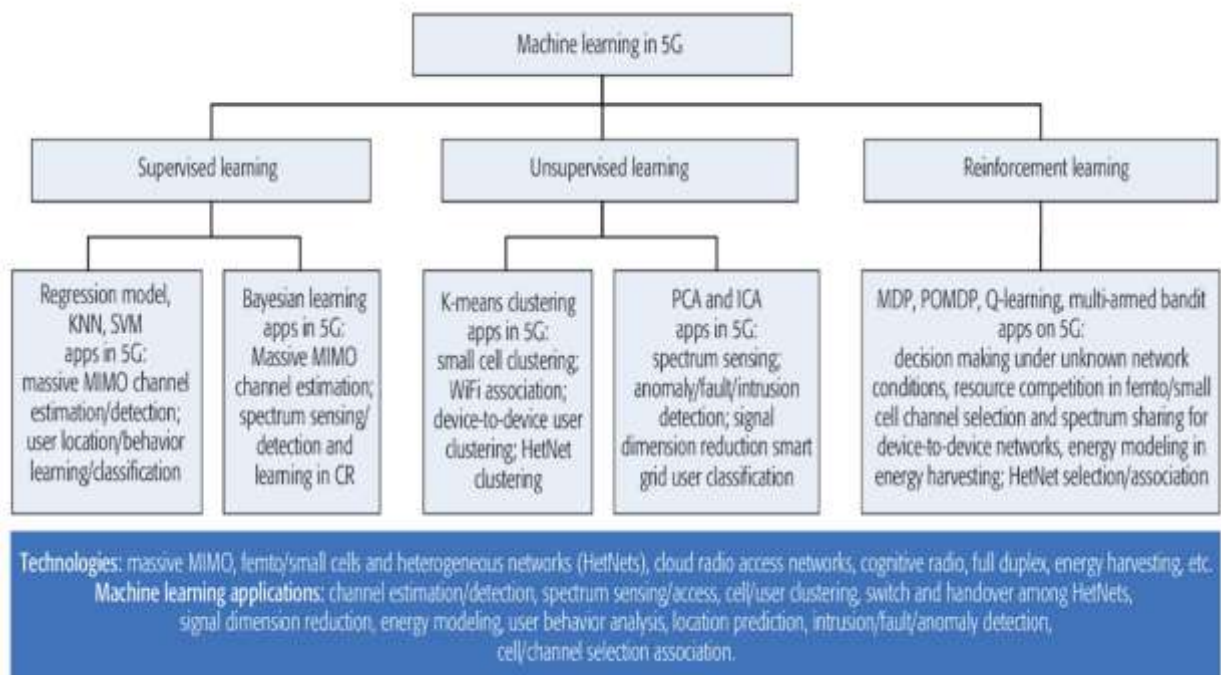
v. The above discussion emphasises that AI models utilise large datasets to train, evaluate, and optimise the models. Data plays a key role in developing an AI model. However, the following question may arise while leveraging this data for developing AI/ML models.

    a. Who will provide such datasets?

    b. Who will validate the data?

    c. Who will test the models?

    d. How is such data being collected or generated?

    e. Can such datasets be shared with others?

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[26] https://www.guavus.com/wp-content/uploads/2018/10/AI-in-Telecom-Operations_Opportunities_Obstacles-2.pdf

f. Does it require consent of the users?

g. How does it ensure privacy?

vi. There are many such questions which are required to be answered before developing any AI model. Further, with emergence of big data in analysis and visualisation of extensive datasets with heterogeneous characteristics give rise to variety of such questions such as what is big data, how traditional data is different from big data and many more. All such questions are required to be answered before leveraging these technologies in telecom sector. Thus, to answer all such questions, it is necessary to understand big data and its related terms which are discussed in detail in following sections.

2.3. Big Data (BD): Definition, Fundamentals, Topology and Role in Decision Making

The evolution from automation to AI is inherently connected with the proliferation and use of huge quantum of data which is popularly known as Big Data (BD). The following sections describe what BD is and how big data plays a key role in supporting decision making which further contributes to AI. Also, the sections cover factors that accelerate the growth of AI, risks associated with AI among others.

2.3.1. What is BD?

BD generally refers to technological developments related to data collection, storage, analysis and applications. The International Telecommunication Union (ITU) defines BD *as "a paradigm for enabling the collection, storage, management, analysis and visualisation, potentially under real-time constraints, of extensive datasets with heterogeneous characteristics".*

2.3.2. How BD is different from traditional data?

Traditionally, data was stored in well-defined structured format which made it easy to store and access for further processing. The traditional data includes household surveys, institutional records or censuses,
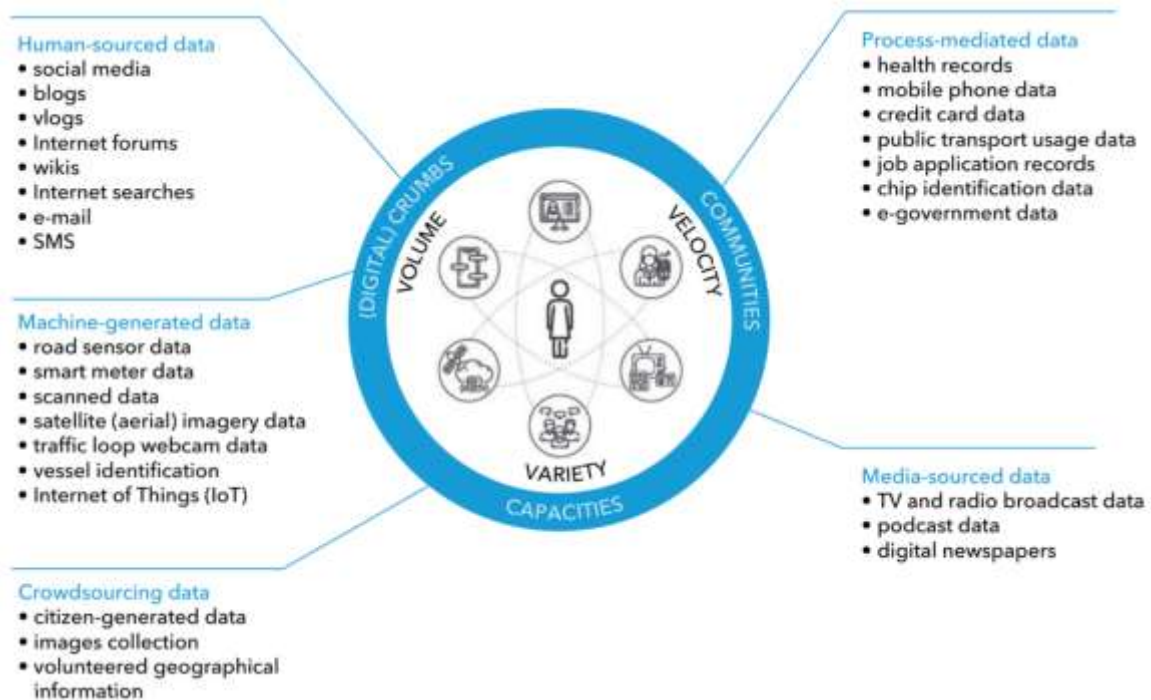
complaint records, etc. The sources of traditional data include Enterprise Resource Planning (ERP) transaction data, Customer Relationship Management (CRM) transaction data, financial data, organisational data, web transaction data etc. It was stored locally as well as centralised, and accessed by using tools like Structured Query Language (SQL). However, with advancements in technologies, a network consists of millions of connected devices, each device generating large amount of data in different formats. It becomes difficult for traditional tools to access and process such heterogeneous large volumes of data. Today, the source of data may be any point, from an actuator to smartphones including social media, device data, sensor data, video, images, audio etc. The complex data so generated is present and distributed across the globe. Thus, with increase in complexity in handling large volume of data, advanced tools such as Hadoop, Spark were developed and now they have become popular for accessing and processing data.

2.3.3. **Fundamentals of BD**

Most of the organisations and companies stated that BD is characterised by the volume, velocity and variety of data being produced ("the three Vs"). However, as per report[27] published by ITU, BD is characterised by the 4 "Vs": Volume, Velocity, Veracity and Variety. Variety refers to structured, unstructured and semi-structured data that are gathered from multiple sources. Veracity refers to the biases, noise and abnormality in data. Velocity refers to both how fast data is being collected and how fast data is processed by big data technologies to deliver the expected results. Volume refers to the large volumes of data that are generated on a daily basis from various sources. The report mentioned social media, call detail records, sensors, web scraping and satellite imagery are just a few new sources of data. A few forms of Big Data are shown in figure 2.7:

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[27] https://www.itu.int/dms_pub/itu-d/opb/tnd/D-TND-02-2021-PDF-E.pdf

Figure 2.7: Forms of big data

Human-sourced data
• social media
• blogs
• vlogs
• Internet forums
• wikis
• Internet searches
• e-mail
• SMS

Machine-generated data
• road sensor data
• smart meter data
• scanned data
• satellite (aerial) imagery data
• traffic loop webcam data
• vessel identification
• Internet of Things (IoT)

Crowdsourcing data
• citizen-generated data
• images collection
• volunteered geographical
  information

Process-mediated data
• health records
• mobile phone data
• credit card data
• public transport usage data
• job application records
• chip identification data
• e-government data

Media-sourced data
• TV and radio broadcast data
• podcast data
• digital newspapers

(DIGITAL) CRUMBS — VOLUME
COMMUNITIES — VELOCITY
VARIETY
CAPACITIES

2.3.4. BD Topology

i.   ITU in its report[28] categorises data in three categories which are discussed below:

    a.   **Structured data:** The data often stored in databases, used mostly in programming and computer-related activities come under structured data which can be generated either by human or machines. The data which human feeds into a computer for example name and other personal details are considered as humans generated structured data whereas all data received from sensors, weblogs, financial systems, medical device data, GPS data and usage-statistic data captured by servers and applications are considered as machine-generated structured data.

    b.   **Semi-structured data:** The dataset which do not conform to the formal structure of data models and contain tags or

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[28] https://www.itu.int/dms_pub/itu-d/opb/tnd/D-TND-02-2021-PDF-E.pdf

markers to identify the such data come under semi-structured data. For example, photos and videos may contain tags related to the location, date, or by whom they were taken, but the information within has no structure.

c. **Unstructured data:** The dataset which do not have a pre-defined data model and are not organised in any defined manner come under unstructured data. Satellite imagery data, scientific data from various experiments and radar data captured by various technologies, social media data, mobile data and website content found on the Internet fall in the category of unstructured data.

ii. ITU also highlighted another classification of big data that reflects whether the data have been produced intentionally or unintentionally and whether they were generated by human or machines. Following types of big data are worth mentioning:

a. **Metadata (data about data):** This term is used to classify, categorise, and retrieve data files. Metadata facilitates data analysis by assigning attributes (e.g., date of data creation, number of pages, data size and keywords) to existing data. For example, each book has a number of standard metadata on the covers and inside. This includes a title, author name, publisher and copyright details, description on a back, table of contents, index, and page numbers etc.

b. **Data exhaust:** This type of data is unintentionally created by humans and generally has low value. It is basically the trail left by millions of users, which can, however, be mined to extract value. For instance, Call Detail Records (CDR) metadata derived from mobile phones or data trails left by users engaged in other activities, such as keystrokes (e.g., from a log file or cookies) fall under data exhaust.

c. **Human-sourced (citizen-generated) data:** This type of data is

intentionally created by humans through their social media presence, videos, academic papers, and blogs, which can be mined. By compiling, combining and anonymizing thousands or more of these types of data, popular or emerging trends can be analysed.

d. **AI-sourced data:** These data are also intentionally created, though by AI rather than humans. For instance, secondary data can be created by chatbots assisting users with filling out online forms.

e. **Personal data:** An information that relates to an identified or identifiable individual.

f. **Non-personal data (NPD):** Data that either never related to an identified or identifiable natural person or have been sourced from personal data excluding any personal identifier, i.e. data which were initially personal but have since been aggregated and/or anonymized.

g. **Open data:** Publicly available data that can be universally and readily accessed, used, and redistributed free of charge.

2.3.5. **Big Data Analytics**

Big data analytics involve a number of steps that are crucial in obtaining relevant insights. These steps and processes are represented in an architectural framework that supports analytics in an organised manner. Before analytics begin, the data must be collected from both internal and external sources. Authenticity and quality of data plays an intrinsic role in determining the value of insights. The framework of Big Data Analytics involves following processes:

i. **Data Collection:** The gathered data is present in raw form collected from heterogeneous sources which exhibits a variety of data structures. There are two kinds of sources, internal sources which includes operating systems, business systems etc. and the external

sources that include market research agencies, complaints etc. For processing, data should be collected in matrix form having high dimensionality.

ii. **Data Pre-processing and Analysis:** The gathered data contains redundancy, inconsistency, and useless information. This semi structured and unstructured data cannot be directly stored in relational databases (with neat tables of rows and columns). To avoid unnecessary storage space, and ensure the processing efficiency, the data should be pre-processed using techniques like integration, cleaning, redundancy elimination etc. to be ready for data analysis, before it is transmitted to the storage systems.

iii. **Big Data Analytics platforms and tools:** After ensuring the quality and removing inconsistencies, data can be fed to analytics tools such as Apache Spark, Hadoop etc. which are open-source software frameworks for distributed storage and distributed processing of large-scale datasets. Hadoop is a software framework for distributed storage and distributed processing of large sets of data. Similarly, Apache Spark is a platform for large scale data processing that is well suited for iterative machine learning tasks.

2.3.6. **BD Supporting Decision Making: Predictions, Algorithms and AI**

With the increased availability and use of data, decisions are increasingly being facilitated or sometimes even completely taken over by using predictive modelling methods, often referred to as the use of algorithms. Using data to predict incidents or behaviour is a major part of developments related to AI. Using AI for BD is a logical step for companies looking to maximise the potential of big data. AI systems use data-driven algorithms and statistical models to analyse and find patterns in data. This is different from traditional rules-based approaches that follow explicit instructions. Big data provides raw material by which AI systems can derive insights. Many organisations are now realising the benefit of combining big data and AI. Following are the examples of how adoption of AI for BD benefits the organisations.

i. Netflix uses ML algorithms for better understanding the users, and providing more personalised recommendations. This keeps the user on their platform for longer period and creates an overall positive customer experience.

ii. Google uses ML to provide users with a highly valuable and personalised experience. They are using ML in a variety of products including providing predictive text in emails and optimised directions for users looking to get to a designated location.

iii. Starbucks is using big data, AI to provide personalised emails using data from customers' past purchases. Rather than crafting only a few dozen emails on a monthly basis with offers for the broad Starbucks audience, Starbucks is using its "digital flywheel" with AI-enabled capabilities to generate over 400,000 personalised weekly emails featuring different promotions and offers.

iv. Topic Data[29] is a Facebook technology that displays to marketers the responses of the audience about brands, events, activities, and subjects in a way that keeps their personal information private. Marketers use the information from topic data to selectively change the way they market on the platform as well as other channels. With Topic Data, Facebook has grouped the data and stripped personal information for user activity to help marketers by offering insights on all the possible activities related to a specific topic. This gives marketers an actionable and comprehensive view of their audience, which can be further improved by adoption of AI.

2.3.7. The discussion so far emphasises on how BD plays a key role in decision making for AI models. Big data contributes in analysing and visualisation of extensive datasets with heterogeneous characteristics. It also helps AI in predictions from the available datasets and utilising those predictions for improving the services. With the support of BD analytics, AI systems can learn, think and perform tasks by using past

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[29] https://www.simplilearn.com/how-facebook-is-using-big-data-article

knowledge and learnings acquired through various scenarios. For example, the predictions from the information of traffic flow for an area help in providing customised services or personalised services to the customers of that area. The telecom sector also generates vast amount of such data at each and every node which is discussed below. This data along with AI may open up play new opportunities for telecom sector.

2.3.8. **BD in Telecom**

i. Telecommunications industry generates and stores tremendous amount of data. These include call detail data, which describes the calls that traverse the telecommunication networks; network data, which describes the state of the hardware and software components in the network and customer data, which describes the telecommunication customers. Globally, average usage per smartphone now exceeds 10GB per month, and is forecasted to reach 35GB by the end of 2026. It is also forecasted that in 2026, 5G networks will carry more than half of the world's smartphone traffic.

ii. With the increasing adoption of smartphones and growth in mobile internet, telecom service providers today have access to exceptional amounts of data sources including customer profiles, device data, call detail records, network data, customer usage patterns, location data, data combined together may become the Big Data, which was discussed in the previous section.

Table 2.1:   Big Data in Telecom[30]

Network Infrastructure	Product	Marketing & Sales	Customer Care	Billing
• Network Events • Call records (on and off network) • Number of text and multimedia	• Product catalogue • Product life-cycle data • Product and	• Customer Devices • Option preferences • Sales channel data	• Order data • Contact data • Fault handling data	• Call duration records • Traffic data • Usage history

[30] https://www.tatatelebusiness.com/whitepapers/big-data-and-the-telecom-industry/

27

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messages	platform costs	○ ARPU classification	○ Problem type	● Customer account data
● Volume of data traffic	● Innovation roadmap	● Response rate of marketing campaigns	○ Resolution time and rates	
● Location-specific data	● Product usage	● Segmentation data	○ Repeated faults	
● User handset data	● Critical Products	● Usage patterns		
● Technical fault data	● Product delivery management	● Subsidy levels	● Call centre logs	

iii. Following are some case studies of Big Data Analytics in mobile cellular networks:

a. **Big Signalling Data**[31]: In mobile cellular networks, the transmission of voice and data is accompanied by control messages, which are termed as signalling. The signalling works according to the predefined protocols and ensures the communication's security, reliability, regularity and efficiency. Signalling monitoring plays an important role in appropriate allocation of network resources, improving the quality of network services and real-time identifying network problems, and many more. With the rapid development in various mobile cellular networks, the volume of signalling data grows tremendously and the traditional signalling monitoring systems may be not having requisite capabilities to handle such voluminous data. Figure 2.8 describe signalling data monitoring and analysing system architecture with big data analytics. This architecture mainly consists of three components: data collection, data analysis and applications. In data collection, various signalling protocols are copied from multiple network interfaces without interrupting normal operations. Afterwards, these copies are gathered and filtered through the protocol processor and then sent to the analyser.

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[31] https://ieeexplore.ieee.org/document/7429688

In the analyser, the data is processed using various algorithms, such as decomposition and correlation analysis. Finally, the analysis results can be used by various applications.

Figure 2.8:   The Big Signalling Data in Cellular Networks
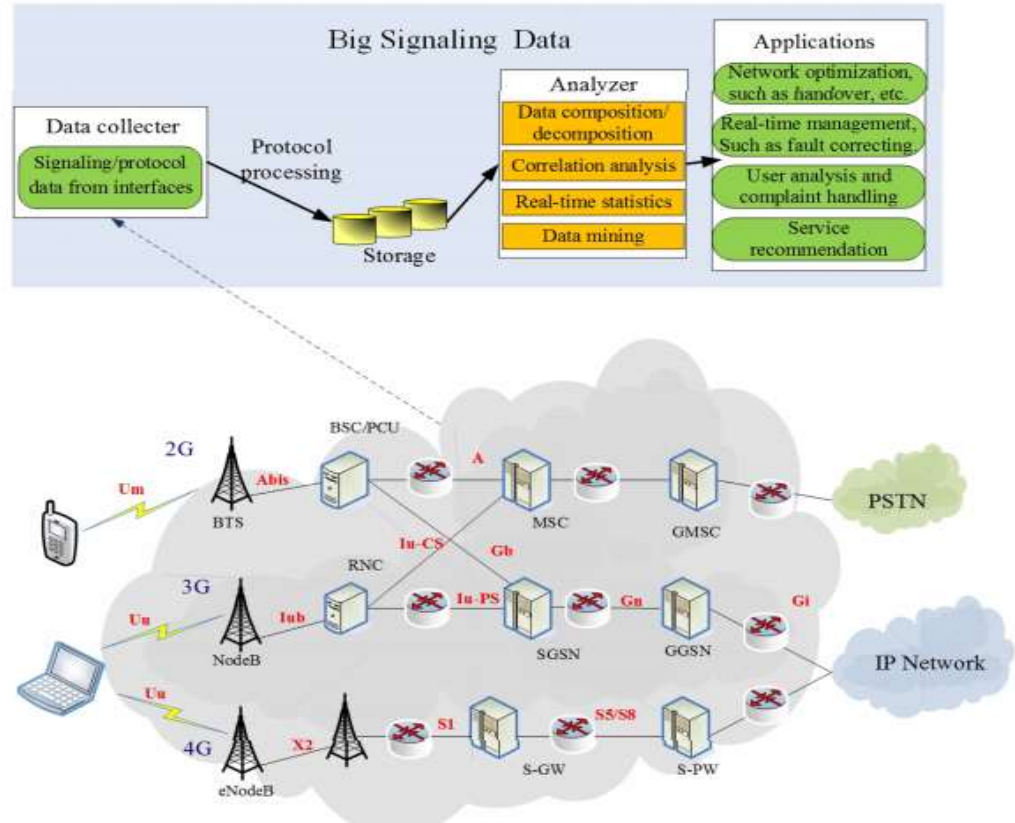
b. **Big Location Data**[32]: Human activities are based on locations, and analysis of location data is informative. As illustrated in Figure 2.9, the location based big data is generated by GPS sensors, WiFi, and Bluetooth through mobile devices. These datasets can be helpful in planning, transportation, constructions, understanding demographic trends, and many more. It can also gain amazing business insights, such as mobile advertising and marketing. An end-to-end Hadoop-based system was developed with a number of functional algorithms operated on Call Detail Records (CDRs). By analysing information about subscribers' habits and interests,

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[32] https://ieeexplore.ieee.org/document/7429688

the systems is capable of providing valuable information about when, where and how the individuals (e.g., sports fans, music lovers, etc.) move.

Figure 2.9:   Big Location Data in Mobile Cellular Networks
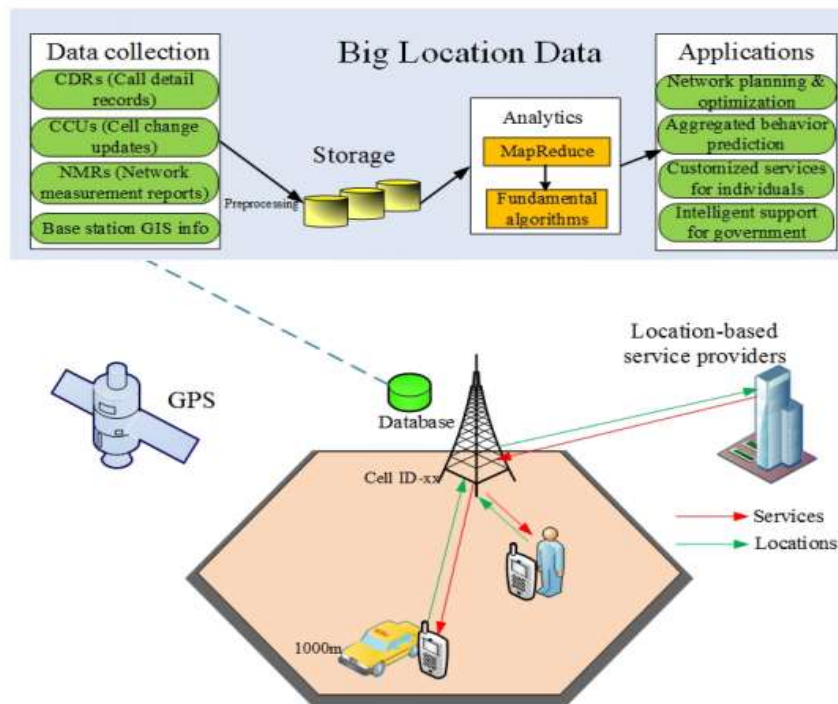
c. **Network Management[33]:** The current Network Management Interface (NMI) model is being challenged as society enters in a new era where enormous amounts of Big Data is available at a comparatively very low cost. The recent advancements in data analytics enable a case for un-instrumenting Network Equipments (NEs) by relieving them of supporting any protocols. Application of AI/ML, big data and data lakes with very fast data transfer rates will free NEs from the unnecessary additional burden of instrumenting NMIs protocols. It will provide for more efficient utilization of NE resources to focus on its core functions with significant improvements in performance of packet processing rate to achieve the desired low latency requirements of a 5G network.

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33   https://www.5gamericas.org/wp-content/uploads/2019/11/Management-Orchestration-and-Automation_clean.pdf

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2.4. Technological Advancements: Catalyst for the Growth of AI

The intelligence of AI depends on the various elements i.e. data, algorithm, model, etc. Artificial Intelligence operates via means of processing data through algorithms. It combines massive data units with its algorithms, gaining knowledge from that data. Following are the key factors that accelerate the growth of AI:

2.4.1. The explosion of data availability through connected devices

As discussed in para 2.2.3, the data acts as fuel in the learning, training, and validation phase of the modelling in the AI. Also, it is a known fact that "*the greater the number of features in AI operations, the greater the amount of data needed*" and "*greater is the number of devices, the greater amount of data will be generated*". The Internet of Things (IoT) is finding its way across various industries and applications, and the data generated from these devices is creating new opportunities to improve business outcomes. IDC[34] predicts that by 2025 there will be 55.7 billion connected devices worldwide, 75% of which will be connected to an IoT platform. IDC estimates data generated from connected IoT devices to be 73.1 Zeta Byte by 2025, growing from 18.3 Zeta Byte in 2019. Thus, the rise of connected devices has created an explosion of the availability of data which will accelerate the adoption of AI.

2.4.2. Advancement in AI Computing Infrastructure

i. As technology advances, the hardware used in computing is upgraded to meet the demands. The present trend of usage of the computing Infrastructure has changed a lot in the last two decades. Initially, the focus was more on the processing of scalar data by using a CPU based system with single or multi-core processors. Later, CPUs were followed by Graphics Processing Units (GPUs). A GPU's speed and efficiency are much faster than the CPU. It renders images and
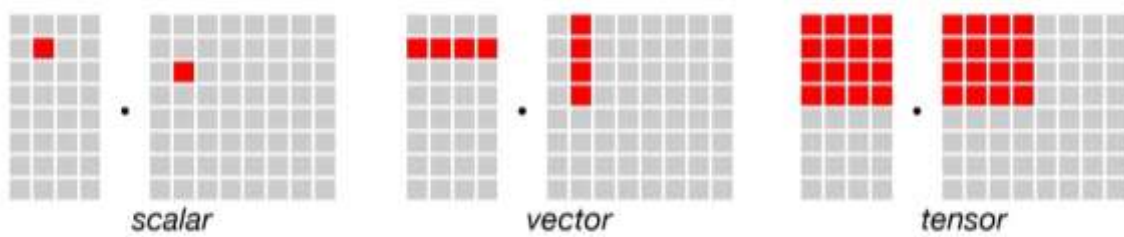
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[34] https://informationmatters.net/internet-of-things-statistics/#:~:text=Summary%3A%20%E2%80%9CIDC%20predicts%20that%20by,from%2018.3%20ZB%20in%202019.

graphics quickly. A GPU can perform tasks in a parallel way as it consists of thousands of cores. GPU uses these cores and has the capacity to perform multiple tasks as per cycle.

ii. Tensor Processing Unit (TPU) is the most advanced form of a processing unit. It is used on a commercial basis (in supercomputers and heavy machines). These are specially designed for machine learning and artificial intelligence software. Initially, it was developed by Google in 2017. With the help of TPUs, Google enhanced its machine learning mechanism and neural networks. TPU is much faster and works efficiently. They are designed to do some single tasks in supercomputers.

iii. Medium[35] highlights that the differences between CPU, GPU and TPU are based on the ability to perform several operations as per cycle. The smallest unit of data handled at a time in CPU is a Scalar which is 1x1 dimensional data. On the other hand, GPUs can perform tens of thousands of operations at a single time. It is much faster and more reliable than the CPU. Because the dimension of data is generally 1 x N data unit per cycle. CPUs are best at handling single, more complex calculations sequentially, while GPUs are better at handling multiple but simpler calculations in parallel. But the problem of memory access is still there. Because GPU performs parallel computation on thousands of Arithmetic Logic Units (ALUs), so it also spends more energy on memory access. To overcome this problem Google designed TPU. TPU is the most complex chip for computers. It can manage Thousands of thousand operations in one cycle. Its performance and speed are much higher than the other both. This is because it can operate N X N data units in one cycle. Also, TPU solved the memory access problem. The computation difference between them is shown in figure 2.10.

35 https://medium.com/analytics-vidhya/cpu-gpu-tpu-ml-perspective-1f049cd4d43d

Figure 2.10: Computation difference between CPU, GPU and TPU


scalar · vector · tensor

2.4.3. Adoption of AI-Specific Hardware and Chips

i. Until recently, almost all AI computations were being performed remotely at respective data centers, on enterprise core appliances, or on telecom edge processors and not locally on devices. This is because AI computations are extremely processor-intensive, requiring hundreds of (traditional) chips of varying types to execute. The hardware size, cost, and power drain made it essentially impossible to house AI computing arrays in anything smaller than a footlocker. Now, edge AI chips are changing all that. They are physically smaller, relatively inexpensive, use much less power, and generate much less heat, making it possible to integrate them into handheld devices such as smartphones as well as non-consumer devices such as robots. By enabling these devices to perform processor-intensive AI computations locally, edge AI chips reduce or eliminate the need to send large amounts of data to a remote location thereby delivering benefits in usability, speed, data security and privacy.

ii. Further, not all AI computations have to take place locally. For some applications, sending data to be processed by a remote AI array may be adequate or even preferred. For instance, when there is huge volume of data for a device's edge AI chip to handle, remote processing may be preferred. In fact, most of the times, AI will be done in a hybrid fashion: some portion on the device, and some in the cloud. The preferred mix in any given situation will vary depending on exactly what kind of AI processing needs to be done.

iii. Deloitte forecasted[36] that the adoption of edge AI chips by devices will grow from 750 million devices in 2020 to 1600 million devices in 2024. Smartphones are not the only devices that use edge AI chips; other device categories like tablets, wearables, smart speakers, contain them as well. The forecast figures are shown in the figure 2.11.

Figure 2.11:   The Edge AI chip growth
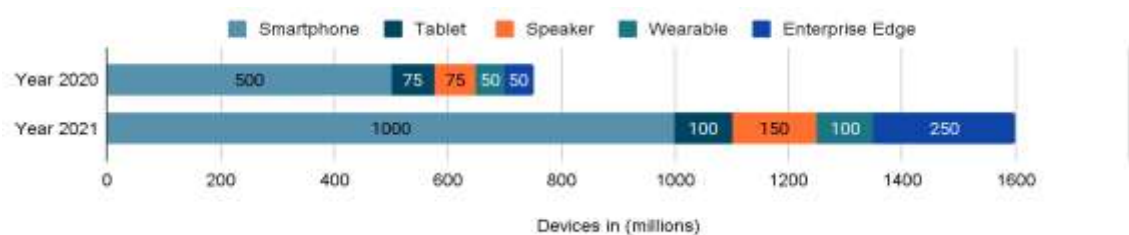
iv. Currently, only the expensive smartphones are likely to use edge AI chips. The term "AI chip," refers to the portion of the overall silicon die that is dedicated to performing or accelerating machine learning calculations. The following are some example of AI chips:

   a. Kirin 980 by Huawei, an artificially intelligent chip enables higher intelligence to phones, unparalleled battery life, powerful camera, and more.

   b. Exynos 9820 by Samsung, flaunts a dedicated Neural Processing Unit (NPU) to handle smartphones AI functions like Image recognition, translation, speech transcription on the device itself with greater efficiency.

   c. A12 Bionic by Apple, features a graphics processing unit and a Neural Engine which powers an artificial intelligence accelerator.

   d. An AI chip named 'SAPEON X220', by SK Telecom (SKT), optimally designed to process artificial intelligence tasks faster, using less power by efficiently processing large amounts of data

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[36] https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2020/ai-chips.html

in parallel.

v. The recent development of a new kind of computing architecture similar to the processing of information by a biological brain is known as neuromorphic computing. One of the most promising forms of neuromorphic computing uses "spiking neural networks" to emulate the way a biological neuron fires (or "spikes") to transmit a signal before returning to a silent state.

2.4.4. **Shift from Clustered (Centralised) Computing Processes to Cloud and Edge (Distributed) Computing Processes**

i. The computing technology has evolved from centralised mainframe computing to edge computing where computing occurs at edge devices installed near to the users. This evolution involves several other stages as shown in the figure 2.12.

Figure 2.12:   Trend of computing technologies
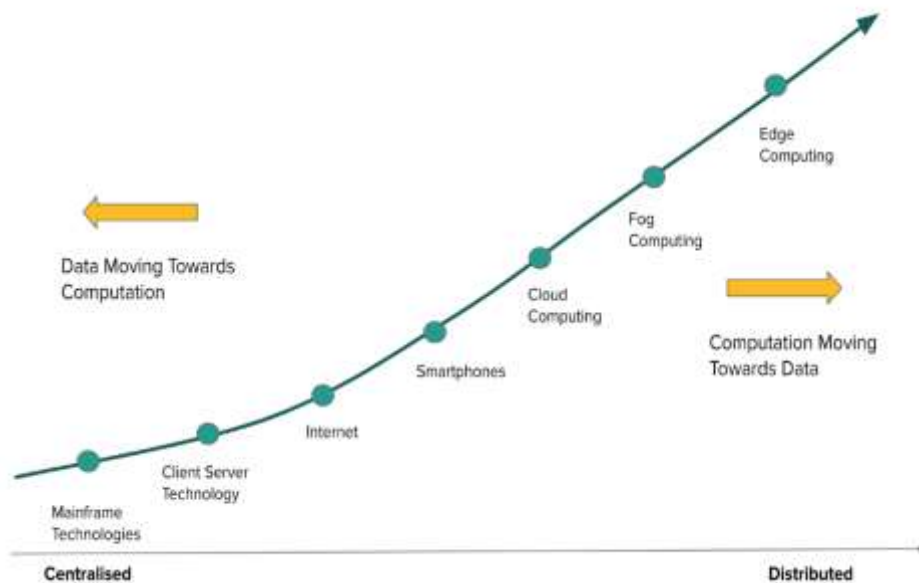
ii. Earlier, data was transferred from devices to the mainframe for computation, and now the data remains within the device and the computation occurs at the edge. As discussed above, various AI chips are being manufactured for the purpose of edge computing to solve the issues of privacy and reduce the latency by performing

computation at the edge.

2.4.5. **Recent developments in learning models**

From being the area of computer science, AI has clearly moved on, adding the understanding of psychology, neuroscience etc. Synonymous with the word AI, words like deep learning, neural network have become quite popular. The figure 2.13 depicts the journey and relations between them.

i. **Deep Learning:** Deep learning is a class of machine learning algorithms inspired by the structure of a human brain. In a neural network, the information is transferred from one layer to another over connecting channels. They are called weighted channels because each of them has a value attached to it. Deep learning models have exceeded expectations in terms of performance and arriving at the state-of-the-art results.

Figure 2.13:   Evolution of AI
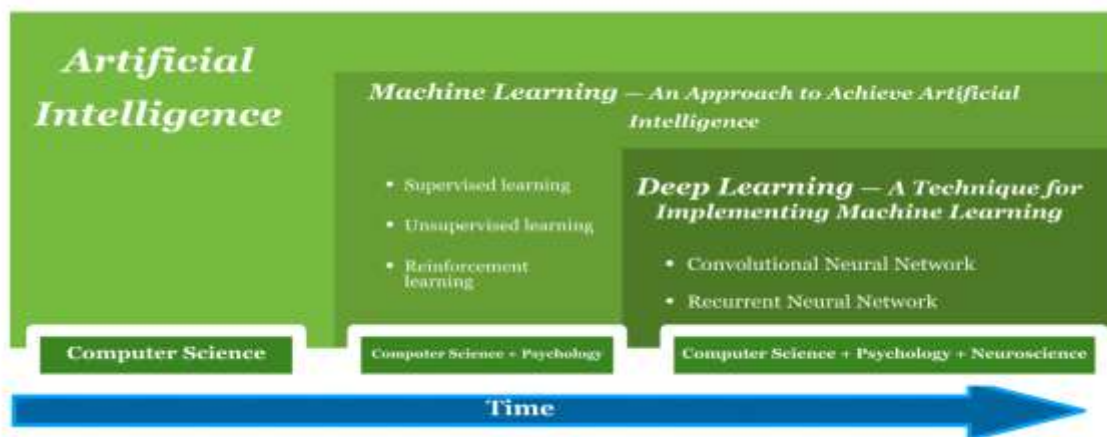
ii. **Artificial Neural Networks (ANN):** Inspired by the human brain and its functioning, a network of artificial neurons is connected which mimics the neurons in the human brain. Training the network using a nuanced dataset establishes weighted connections which eventually activates certain neurons upon receiving certain input. For instance, the fragrance of a flower activates certain neurons in the human brain which is distinctly different from that

in the case of a burning wooden log. Similarly, perceptrons (artificial neurons) are trained by an extensively large dataset.

iii. **Convolutional Neural Networks (CNNs):** Connections between neural networks are inspired by the organisation of the animal visual cortex (Portion of the brain that processes images) well-suited for perceptual tasks.

iv. **Graph Neural Networks (GNN):** Recently another neural network known as Graph Neural Networks (GNN) received a lot of attention. GNNs have the ability to understand graph structured data. GNN extends the existing neural network for processing the data represented in graphs. In GNN, the idea of "time step" or "sequence" becomes flexible. Producing a sequence of outputs can be thought of as walking the graph, with each step predicting the next node, based on the graph's structure and a history of nodes visited. ITU has recently launched ITU AI/ML in 5G Challenge: Graph Neural Networking Challenge 2020. This competition has invited innovators worldwide to develop Artificial Intelligence /Machine Learning (AI/ML) solutions for 5G networks.

v. **Generative Adversarial Networks (GANs):** GANs are major breakthrough, endowing deep networks with the ability to produce artificial content such as fake images that pass for the real thing. GANs consist of two interlocked components, a generator, responsible for creating realistic content, and a discriminator, tasked with distinguishing the output of the generator from naturally occurring content. The two learn from each other, becoming better and better at their respective tasks over time. Two Neural Networks contesting one other in a zero-sum game framework (thus "Adversarial"). It can learn to mimic various distributions of data (e.g. text, data, speech, and images). It is valuable in generating test data sets when these are not readily available.

In the past decade, machine learning technologies have moved from the

academic realm into the real world in multitude of ways which are both promising and cause of concern.

2.4.6. 5G Plus AI: Connected Intelligent Edge

The AI and 5G will be the key components that fuel the future innovations. These technologies when combined together will work synergistically. This means AI advancement will work towards improving 5G systems performance and efficiency while expansion of 5G will drive distributed intelligence through connected devices. Further 5G will generate massive amounts of data from multitude of new services, and billions of IoT devices, which will enhance AI learning and model training. This synergy between AI and 5G is discussed in detail in following section:

i. AI for 5G

With the increase in interconnected devices, the traffic and demands of the network will increase constantly. Heterogeneity is expected to characterize the increase in connected wireless devices and mixed usage of cells of diverse sizes and access points with different multi-radio technologies. The industry and academia are embracing 5G as the future network capable of supporting next generation vertical applications with different service requirements. To realise this vision in 5G network, physical network has to be sliced into multiple isolated logical networks of varying sizes and structures, dedicated to different types of services based on their requirements and characteristics. With all these, the network would be characterised by increased traffic, various mobility levels and interference. In addition to this, multiple requirements such as Quality of Experience (QoE), resource efficiency, energy-efficient operation and cost efficiency need to be taken into account. To manage all these requirements in real time, there is a need for enhanced intelligent systems with programmable capabilities. The softwarization of network using Software-Defined Networking (SDN) and Network Function Virtualization (NFV) in 5G networks is expected to fill the void of programmable control and management of network resources.

38

Further, as per a report by 5G Americas[37], Telemetry data analytics-based statistics from Network Data Analytics Function (NWDAF) and RAN Data Analytics Function (RAN-DAF), combined with AI/ML, will allow operators to dynamically optimize their networks and automate 5G network slicing management.

The integration of AI with softwarization of network will make the network more flexible and agile by programming the network intelligently. The AI enables faster decision making by gathering and processing network data in real time and automating network functions, so service providers can switch from reactive to proactive mode. In self-healing networks, AI systems are trained to look for patterns, detect, predict and localize network issues, and take proactive steps to fix the service before customers are impacted. This also has the benefit of freeing up IT professionals' time that would otherwise be spent on troubleshooting and repetitive tasks, letting them focus instead on strategic initiatives. As a result, AI will be able to support truly dynamic networks and services, accurately reflecting the prevailing state of the network with an up-to-date view of physical and virtual resources, while at the same time providing a complete historical record of the network to support cross-domain hybrid service orchestration and assurance.

ii.   5G for AI

While AI is supporting the effective management of 5G network and its services, there is a complementary role of 5G to drive rapid developments in AI. The high bandwidth, massive connectivity, and low latency capabilities of 5G will drive the development of IoT services by connecting massive devices. These interconnected devices will generate large amount of data to be used for training and modelling AI. Further, the low latency and high capacity of 5G will also allow AI processing to be distributed among the device, edge cloud, and central cloud, enabling flexible system solutions for a variety of new and enhanced experiences.

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[37] https://www.5gamericas.org/wp-content/uploads/2022/01/Cellular-Communications-in-a-5G-Era-InDesign.pdf

The on-device (networked devices) training has following important benefits that will lead to mass adoption of AI:

a. **Scale:** Connecting massive devices can harness a significant amount of computational power by distributing processing over many devices, such as millions of smartphones.

b. **Personalization:** The AI model learning is inherently customised with data used for on-device training.

c. **Privacy:** Extracting the value of the data and preserving privacy is possible by training on devices.

d. **Speed:** On device training would overcome the potential issue of transfer of data such as data transmission delay or loss, which would result in inconsistent service performance, thus on device training improves speed and precision.

e. **Real Time:** Real-time processing is a fundamental advantage of on-device training. It supports delay-sensitive applications and services such as remote surgery, tactile internet, unmanned vehicles, and vehicle accident prevention.

The AI-powered 5G networks will accelerate the fourth industrial revolution and create unprecedented opportunities in business and society.

2.4.7. **AI/ML for 6G:** The 6G is expected to blur the boundaries between digital and physical realities by infusing immersive experience of augmented and virtual realities in every vertical. Intelligent knowledge systems combined with ubiquitous computation will make humans more efficient and redefine their lifestyle, conduct and work environment.

i. 6G is empowered by emerging technologies like AI/ML and digital twin models. The intelligence to learn from data and apply it in the real world is achieved through AI/ML whereas digital twin models are simulations which allow us to analyze

what's happening in the physical world, simulate possible outcomes, anticipate needs and then take productive actions.

ii. A Whitepaper on 6G[38] highlights that evolution of telecom infrastructures toward 6G will consider highly distributed AI, moving the intelligence from the central cloud to edge-computing resources. Another whitepaper on ML in 6G[39] highlights that ML algorithms should be deployed and trained at different levels of the network: management layer, core, radio base stations, and in mobile devices, possibly with the assistance of the network itself (e.g. via configuration and/or device programmability). These new paradigms may drive the need for a ML-native and data-driven network architecture implemented as network functions within the network and management domains, possibly requiring data from different sources. Meanwhile, physical-layer algorithms (e.g. link adaptation), as well as higher layer algorithms (e.g. mobility), can be optimized with the controlled and predictable deployment of ML agents. The role of ML at different layers of 6G networks is shown in figure 2.14.

iii. The era of 6G will bring following changes -

   a. Emergence of man-machine interfaces to control and consume information.

   b. Typing on touchscreen will gradually get replaced by gesture and voice control.

   c. Devices will come embedded into clothing and even transform into skin patches.

   d. Healthcare will be an important benefactor as wearables facilitate 24/7 monitoring of vital parameters and warning

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38 http://jultika.oulu.fi/files/isbn9789526226774.pdf
39 http://jultika.oulu.fi/files/isbn9789526226736.pdf

us of the potential health problems.

    e. Digital cash and keys may become the norm.

    iv. The advanced multi-sensory telepresence that is created with very high data rates will reduce the need for travel through the introduction of multi-modal mixed reality telepresence and remote collaboration.

Figure 2.14:   Role of ML ion 6G networks
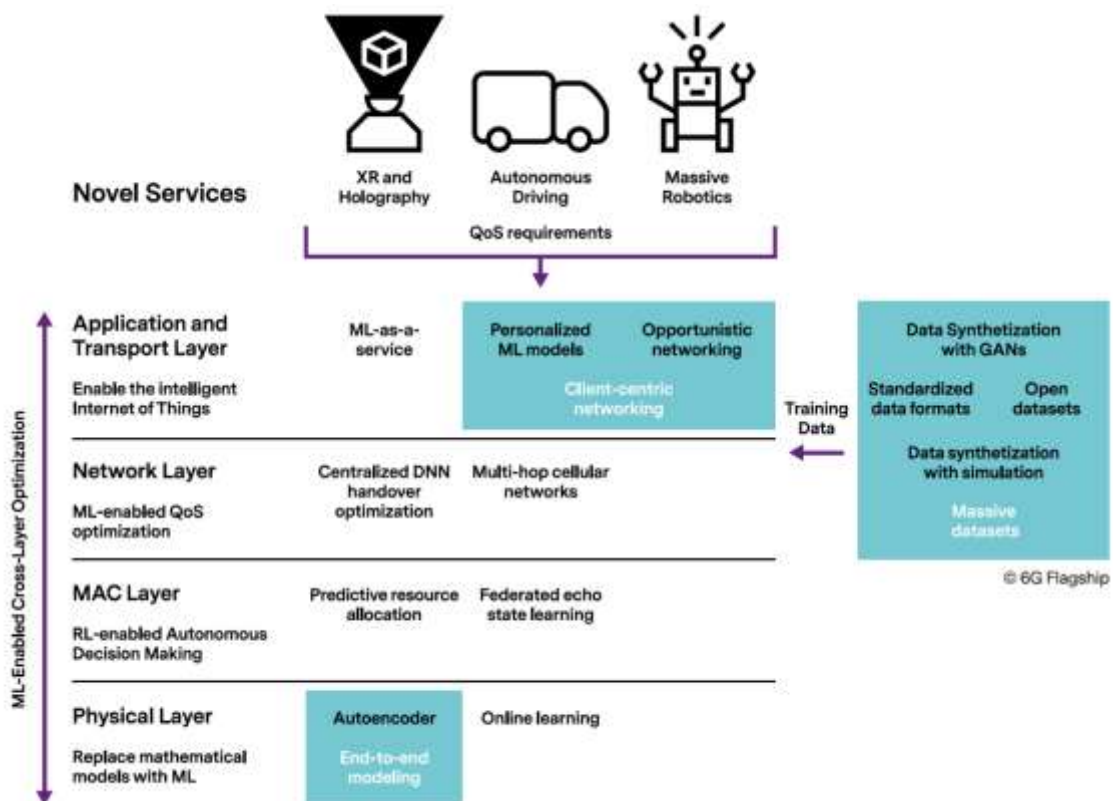
2.5.   Adopting AI with caution

2.5.1.   Many organisations and nations while adopting AI have started focussing on possible risks and challenges associated with it. As the emergence of AI is paving ways for new set of opportunities for everyone, it is important that its inherent risks are also considered and addressed. Risks related to data include data biases, data poisoning, and that related to models include model biases, model extraction., Further, there is a risk of privacy among users which includes data exploitation,

risk of identification and tracking, and individual profiling.

2.5.2. Although Artificial Intelligence is growing and gaining popularity at a rapid rate, it is important to note that AI is still facing number of challenges. Some of the common challenges that most companies face when trying to implement Artificial Intelligence, include limited AI expertise and knowledge, access to quality data, and AI specific infrastructure.

2.5.3. Considering the inherent advantages associated with AI, in order to address the challenges related to trust, new terminologies such as Trustworthy AI, Responsible AI, Explainable AI are being coined by various organisations and nations. Some use these terms to build AI systems following defined principles. Consider the initiative taken up by ITU, AI for Good[40], which aims to bring forward Artificial Intelligence research that contributes towards more global problems through the Sustainable Development Goals. AI, which may be responsible for the fourth industrial revolution, should be used responsibly dealing with the larger problems of humanity as a whole.

   i. **Responsible AI (RAI):** The impetus behind responsible AI is to design, develop and deploy AI with good intentions and to have a positive impact on society. This term "Responsible" has been used by many, for example, google[41] defined principles such as fairness, interoperability, security, and privacy. Microsoft[42] put responsible AI principles into practice through the Office of Responsible AI. The notions of ethical and accountable artificial intelligence (AI) also referred to as "Responsible AI" have been adopted by many stakeholders from government, industry, civil society, and academic institutions. Making AI systems transparent, fair, secure, and inclusive should be the core elements of a responsible AI framework.

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[40] https://ai4good.org/
[41] https://ai.google/responsibilities/
[42] https://www.microsoft.com/en-us/ai/responsible-ai?activetab=pivot1%3aprimaryr6

However, these elements are interpreted and operationalized by each group may vary.

ii. **Explainable AI (XAI):** The magic with which AI can find hidden correlations in ostensibly uncorrelated data sets, is captivating. Unlike traditional paradigms of programming, the AI model requires a rich dataset to learn and create its own logic/ rationale to produce desirable output. However, the concern of people would be understanding how the AI/ML model arrived at a particular decision/prediction/output. Explainable AI is a set of tools and framework to help understand and interpret the model's behaviour. To increase confidence in model and end-user's trust, such initiatives are being taken by companies like google[43], IBM[44], and others. Some of the government initiatives are also active like DARPA's XAI initiatives by USA, among others.

iii. **Trustworthy AI:** In 2019, the EU presented Ethics Guidelines for Trustworthy Artificial Intelligence[45]. According to the Guidelines, trustworthy AI should respect all laws and regulations, respect ethical principles and values, and be robust from a technical perspective while taking into account its social environment.

iv. **Generative AI:** AI is shifting from interpreting existing data to generating novel content at a scale. Generative AI emphasises on the capabilities of AI where it can generate or create something new for example, a new symphony, an artwork, etc, which is based on past learning experiences, Emulating the creative aspect of human beings.

v. **Augmented AI:** Presently, research is focused on improving the capabilities of AI technology. However, augmented AI talks about leveraging AI for enhancing/augmenting human capabilities to process/analyse huge amounts of data. This is crucial because AI is good at identifying underlying patterns in huge data, which can

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43 https://cloud.google.com/explainable-ai
44 https://www.ibm.com/in-en/watson/explainable-ai
45 https://ec.europa.eu/futurium/en/ai-alliance-consultation.1.html

augment human's capabilities. It is similar to the use of exoskeleton technology which increases the strength and agility of humans to perform superhuman feats.

vi. **Embedded AI:** Devices such as smartphones, laptops, and other smart devices are being equipped with AI-enabled dedicated chips. A discussion in para 2.5 highlights the advent of AI-embedded devices. For instance, A12 Bionic by Apple features a graphics processing unit and a Neural Engine which powers an artificial intelligence accelerator. With embedded AI, devices have the ability to run AI models at the device level and then directly use the results to perform an appropriate task or action.

2.5.4. The above discussion emphasizes that advent of AI improves the lifestyle and working environment and efficiency of businesses and individuals. The associated risks and challenges can be mitigated by bringing trust with new terminologies and processes such as Responsible AI, Explainable AI and Trustworthy AI depending upon the use cases and organisational needs. All such terminologies may be required to be generalised for future adoption in the telecom sector.

Issues for consultation

Q.1. What may be the most appropriate definition of Artificial Intelligence (AI)? What are the broad requirements to develop and deploy AI models in a telecom sector? Whether any major challenges are faced by the telecom service providers in adopting AI? Please justify your response with rationale and global practices, if any.

Q.2. Whether the big data in the telecom sector may be utilised for developing AI models? For efficient and effective handling of big data, whether there is a need for adoption of special programming models or software frameworks? Please justify your response with suitable examples and global practices, if

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any.

Q.3. Whether deployment of 5G and beyond technologies will help to accelerate adoption of AI in all the sectors and vice versa? Please justify your response with suitable illustrations including global practices, if any.

Q.4. Do you think that a number of terminologies such as Trustworthy AI, Responsible AI, Explainable AI etc. have evolved to describe various aspects of AI but they overlap and do not have any standardised meanings? If yes, whether there is a need to define or harmonise these terms? Please justify your response with rationale and global practices, if any.

CHAPTER 3

OPPORTUNITIES AND RISKS INVOLVED

3.1. Introduction

3.1.1. In recent times, there is hardly any industry that has not been influenced by AI and BD. AI has been transforming functioning of the various sectors by introducing vast opportunities for the sectors. A Report[46] by Capgemini based on a survey of 1000 organisations shows that in 3 out of 4 organisations which implemented AI, sales of new products and services increased by more than 10%. Operational efficiency improved by more than 10% in 78% of organisations. 75% of organisations using AI enhanced customer satisfaction by more than 10% and 79% of organisations implementing AI generated new insights and better analysis.

3.1.2. Similarly, AI has been transforming the telecommunications industry by offering intelligent automated systems in designing, deployment, maintenance and managing network complexities including proactively securing the network. AI in telecom is expected to make efficient and optimum utilization of telecom resources thereby improving service quality and customers' satisfactions. Also, it offers opportunities to connect the users by improving digital connectivity inside buildings. The following sections cover various such opportunities offered by AI in telecom in detail.

3.2. Opportunities for Telecom Sector

The evolution of AI is creating new opportunities in new market sectors and developments are continuing to drive both service demand and

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[46] https://www.capgemini.com/wp-content/uploads/2018/01/turning-ai-into-concrete-value-the-successful-implementers-toolkit.pdf

development of new telecom applications. The table 3.1 lists out some of the use cases of AI in telecom.

Table 3.1:   Use Cases of AI in Telecom[47]

	China	USA	Europe
Networks	• AIOps for network optimization and operation • Intelligent NFV operation and maintenance platform • Intelligent data center • Intelligent Quality Inspection System	• Disaggregated Network Operating System (dNOS) • AI platform for network faults automatic prediction, self-healing and illegal access prevention • UAV for cell tower inspections	• Centralized-SON • Self-driving network with self-configuration, self-monitoring and self-diagnosis function • Application to find the best available Internet connection • Expansion of the fiber optic network using AI
Service	• Smart home platform • Intelligent online customer service bot	• Smart home automation system • End-to-end service Digital Customer Experience (CX)	• Smart home service • Intelligent assistant • Smart notification platform
Industries	• Smart government platform • Smart police product • Smart vehicle terminal • Medical image cloud • "Super-brain" plan for smart city	• Smart city • Smart glasses and medical platform for people with poor vision	• Smart retail, energy and city business • Smart transportation service and virtual tour service • Radio Positioning System (RPS) for UAVs • Smart agriculture solutions • AR/VR products
Platform	• Intelligent network platform • Smart customers service cloud platform	• Open-source AI platform "Acumos" • Edge computing platform "Akraino Edge Stack"	• AI platform

The following sections discusses the opportunities or use cases of AI in telecom in detail.

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[47] https://www.itu.int/en/ITU-T/Workshops-and-Seminars/201903/Documents/Jun_Liao_Presentation.pdf

3.2.1. Enhancing Overall Quality of Service (QoS)

i. In 2020, when COVID-19 pandemic affected the world, there were limited opportunities for one-to-one or group interactions. The importance and demand of good digital connectivity specially at homes, workplaces, health care systems, educational institutions and various public utility services increased significantly. This change has now become a new norm and is continuing even after the pandemic. Good quality of service and digital connectivity has become essential for all irrespective of their age or profiles.

ii. Adoption of AI and BD in telecom network may play a key role in meeting these demands of users. Leveraging these technologies would enable telecom operators to optimise network quality with smarter detection and anomaly prediction, assisted capacity planning, and self-optimization to respond to changing conditions. Adoption of AI will ensure more reliable services by using historical data and sophisticated algorithms for predictive maintenance. For example, AI may be used in network to manage real time traffic. At initial stage, AI may predominately focus on training and serving the predictions based on static model. This initial training of model will be done on offline data using supervised learning. At later stage, the reinforcement learning paradigm may be used in real time environment where model will interact with real-time data, perform continuous simulations and take necessary actions that impact the real time provisioning of the service. With the passage of time, the AI model based on historical data, can choose any action as a function of the history, and finally optimise the system parameters with the most recent real-time network changes.

iii. The following section cover some of the opportunities of AI and BD in telecom:

    a. **Network Design:** A Report published on the website of Ericsson[48] highlights use of AI in the telecom network design. Network design

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48   https://www.ericsson.com/49f7c8/assets/local/reports-papers/further-insights/doc/improving-customer-experience-and-roi-with-mobile-planning-design-and-optimization.pdf

focuses on identifying ideal site locations and defining the parameters for the cells of the site and cells in its neighbours for network deployment. It is critical that this stage is to be completed quickly and accurately. Furthermore, given the dynamic nature of traffic flow, limitations to budget and growing pressure to deliver a high-quality customer experience, TSPs need to review network designs frequently and take corrective measures more often. Therefore, they require a precise and flexible approach in defining the network parameters to accelerate time to market new services and to remain competitive.

The adoption of AI in network design provides opportunities for TSPs to predetermine cell parameters for a new site and its neighbours. The AI in the network design learns from historical radio network data and based on the learnings AI forms basis to predict network parameters and required design specifications. In the network design the AI can analyse and mine historical data to discover the reasons behind the past successes and failures and then exploit the extracted knowledge and experiences to properly allocate resources, guaranteeing end users with a high quality of experience, self-adaption to system renovation and dynamics.

The AI can also help the network designers by providing 3D modelling of the network environment and its radio performance prior to the actual deployment. These AI models can also take into consideration small objects such as trees and building materials that traditional planning tools may omit. This level of granularity is particularly critical to the millimetre wave and even higher spectrum because the propagation of signals is affected by these objects. The AI not only helps in designing the network but it also optimises the design after deployment. It can also be updated regularly to ensure an accurate view and allocation of radio resources in line with customer expectations.

AI supports network design process which result into better predictions in prioritising sites for network upgrades. It also gives

scalability and flexibility in resource allocation that is not provided by the static propagation models used in most networks today.

b. **Improving digital connectivity inside buildings:** A good digital connectivity would require coherence in planning of networks inside buildings and backhaul from which the building network can be easily hooked on. The alignment required is not only in terms of technical match of the components but also in terms of time when services should be available. The AI may be used in developing a model of the building from connectivity perspective, that may analyse the QoS at each corner of a building. In this case, the AI may learn the behaviour of the network for that building based on the parameters of the mobile device for each and every location. Based on the learnings, the AI may predict the best suitable network devices to be installed at a defined location to enhance the connectivity of the building. Further, after installing the proposed devices, the AI can continuously monitor the performance of devices to predict the factors that may degrade the network performance prior to any failure in the network devices. To give a better picture of the building in terms of digital connectivity, users may use their mobile device to run such AI models using techniques like federated learning which help in rating of buildings from digital connectivity point of views at the same time without compromising the information of data.

c. **Traffic Management using AI/ML:** In 2021, ITU launched Graph Neural Networking (GNN) Challenge 2021 "Creating a Scalable Network Digital Twin"[49]. The goal of this challenge was to create a Network Digital Twin solution based on neural networks, which can accurately estimate QoS performance metrics given a network state snapshot. The proposed solution must predict the resulting source-destination mean per-packet delay given: (i) a network topology, (ii) a source-destination traffic matrix, and (iii) a network

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49
https://challenge.aiforgood.itu.int/match/matchitem/31?msclkid=df2956d7b58611eca6c9ba2bfcfc79af

configuration (routing). Particularly, the objective of this challenge is to achieve a Network Digital twin that can effectively scale to considerably larger networks than those seen during the training phase.

The challenge's problem statement brings a fundamental limitation of existing GNNs i.e. their lack of generalization capability to larger graphs. In order to achieve production-ready GNN-based solutions, there may be need of models that can be trained in network testbeds of limited size, and then be able to operate with guarantees in real customer networks which are often much larger in number of nodes. In this challenge, participants are asked to design GNN-based models that can be trained in networks of limited size (up to 50 nodes), and then generalize successfully to larger networks not seen before, up to 300 nodes. Solutions with better scalability properties will be the winners. Use cases of GNN in Telecom[50]:

- **To solve routing complexity in Multipath TCP:** To fully utilize the network resources, multipath TCP is considered for 5G networks, which transfer packets over multiple paths concurrently. However, network heterogeneity in 5G networks makes the multipath routing problem become more complex for the existing routing algorithms to handle. A GNN-based multipath routing model[51] is proposed by many to handle complex routing issues. The experiments under the SDN framework demonstrate that the GNN-based model can achieve a significant throughput improvement.

- **To solve complexity in network slicing:** As a software-based application concept, network slicing has been proposed and also recommended by TRAI for 5G network[52], using network

[50] Graph-based Deep Learning for Communication Networks: A Survey (arxiv.org)

[51] https://arxiv.org/pdf/2106.02533.pdf#:~:text=GNNs%20are%20suitable%20for%20problems,when%20the%20networks%20are%20dynamic.

[52] Recommendations on Auction of Spectrum in frequency bands identified for IMT/5G

virtualization to divide single network connection into multiple distinct virtual connections that provide services with different Quality-of-Service (QoS) requirements. However, the increasing network complexity is becoming a huge challenge for deploying network slicing. A scalable Digital Twin (DT) technology with GNN is developed for mirroring the network behavior and predicting the end-to-end latency, which can also be applied in unseen network situations.

- Traffic prediction is also considered in cellular networks, with GNN-based solutions being proposed in recent years. As a prediction problem, the temporal dependencies may be modelled by a recurrent neural network, e.g. Long Short Term Memory (LSTM) or GRU. Different attention mechanisms may also be incorporated. As an improvement over baselines, GNN is capable of modelling the spatial correlation between different nodes, e.g. a cell tower or an access point.

- Energy consumption is another concern for the 5G network, which is designed to enable a denser network with microcells, femtocells and picocells. GNN-based power control solutions are proposed by many researchers for better control over the transmission power. Heterogeneous GNNs (HetGNNs) with a novel parameter sharing scheme are proposed for power control in multi-user multi-cell networks.

iv. **Use case by telecom operators:** Telecom operators in other jurisdictions (other countries) have started adopting AI/ML in their networks. As per the information published on their website and the report on "AI in Telecom Operations: Opportunities & Obstacles[53]" published by Heavy Reading, telecom operator such as AT&T is using AI/ML for optimising networks; Colt is using AI/ML in Traffic Flow classification, Quality of experience modelling, capacity management, Network scaling; Globe Telecom is using Self Organising Network (SON); Vodafone (UK) is in Trial

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[53] http://www.heavyreading.com/details.asp?sku_id=3558&skuitem_itemid=1781

of ML in C-SON; etc. A list of various applications of AI to improve quality of services is highlighted in Table 3.2.

v. Operators in India deployed AI in areas which include Network Planning (ML assisted smart radio planning, Rural network planning), Network Optimisation & Configuration (Resource Scheduling (BW/Power/Load balancing), Energy saving and efficiency improvement, (Vision based telecom network optimisation), Network Maintenance & Monitoring (Predicting Sleeping cell, Predicting Potential network faults and down time) etc.

Table 3.2: **Lists of various applications of AI to improve quality of services.**

Network Planning	Network maintenance & Monitoring	Network Optimisation & Configuration
- Cell capacity expansion - Classification & Forecasting - Site Deployment - MIMO Placement - Indoor and Outdoor User Experience Differentiation - In-building network coverage - RAN Planning - Radio propagation forecast - Hardware detection	- Prediction of network faults - Dynamic Threshold–based Network O&M Exception Detection - Congestion prediction - Traffic Flow classification - Root cause analysis - Site Maintenance - Virtual Machine failure prediction - Network orchestration - Subscriber mobility & usage pattern - QoS degradation prediction - Alarm failure prediction	- Intelligent access and handover - Intelligent resource scheduling (Bandwidth/ Power/Load balancing) - Intelligent Parameter Adjustment - MIMO beamforming - Energy saving and efficiency improvement (RAN Model for energy efficiency) - VOLTE Optimisation

3.2.2. **Spectrum management**

i. Wireless spectrum has been managed and utilised over many decades

through a complex regulatory framework and policies. These policies are mostly suitable for allocation of fixed frequency bands for a particular type of services and they are often suboptimal and rigid, preventing efficient use of wireless spectrum. The manual process of assessing spectrum needs may be problematic due to the growing level of interdependencies in the spectrum domain. Manual allocation of spectrum so far has yielded satisfactory results but as the number of services using spectrum as resources are increasing exponentially, the demand for spectrum is also increasing exponentially. Further, technology advancements in radio systems, be it back haul and/or access has made spectrum usage more efficient across various bands through software-controlled Radio Frequency (RF) devices.

ii. 5G Services which has varied applications in various frequency bands will be highly reliant on intelligent spectrum management techniques, and therefore will require a dynamic network environment for a high reliability and high quality-of-experience. In this context, use of AI and ML is expected to play a very important role in paving the way towards truly AI-driven spectrum management. Therefore, it has become imperative to adopt AI techniques for an effective and efficient spectrum management in various wireless networks.

iii. A book titled "*Dynamic Spectrum Management: From Cognitive Radio to Blockchain and Artificial Intelligence*" highlights detailed applications on how AI can improve performance of the spectrum through proper management. One of the applications of AI is discussed in the following paras.

Spectrum sensing[54] is an important task to realise Dynamic Spectrum Management (DSM) in wireless communication systems and is normally used to assist users to find out channel occupancy status. In order to increase the accuracy of spectrum sensing, many spectrum sensing algorithms have been developed in recent past. It is noticed that most of

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[54] https://library.oapen.org/bitstream/handle/20.500.12657/23107/1007051.pdf?sequence=1&isAllowed=y

the existing algorithms are model-driven and need prior knowledge of noise or Primary User (PU) signals to achieve good performance. However, this feature makes them unsuitable for a practical environment especially due to lack of prior knowledge, resulting into performance degradation.

To solve above concerns, machine learning techniques have been adopted to develop Cooperative Spectrum Sensing (CSS) framework. CSS framework considers a Cognitive Radio network, in which multiple Secondary Users (SUs) share a frequency channel with multiple Primary Users (PUs). The channel is considered to be unavailable for SUs to access, if at least one PU is active and it is available if there is no active PU. For cooperative sensing, each SU estimates energy level of the received signals and reports it to another SU which acts as a fusion centre. After reports of energy level from all SUs are collected, fusion centre makes final classification of the channel availability. Using machine learning techniques, fusion centre can construct a classifier to detect channel availability. With unsupervised machine learning, detection of the channel availability relies on the cluster in which sensing reports from all the SUs are mapped to. On the other hand, with supervised machine learning, classifier is first trained using the labelled sensing reports from all SUs. After classifier is trained, it can be directly used to derive the channel availability.

iv. **Adaptive Modulation and Coding[55]:** In the 5G mobile communication systems and in Non-Orthogonal Multiple Access scheme, Adaptive Modulation and Coding (AMC) is going to be used heavily. AMC is highly effective in a high-mobility environment. By dynamically allocating resources depending on channel state information and signal-to-noise ratio (SNR) it improves spectrum efficiency and the received signal quality. Complex signal processing techniques for estimating SNR with high accuracy can cause feedback delay and degrade the throughput

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[55] https://www.researchgate.net/publication/336275432_Adaptive_Modulation_and_Coding_Using_Neural_Network_Based_SNR_Estimation

performance. Using an Artificial Neural Network (ANN) for estimating the SNR values drastically improves the latency and processing speed at the base station. The power spectral density values can be trained for SNR classification and mapped to the respective modulation and coding scheme using supervised learning. Once the neural network (NN) is trained, the Modulation and Coding Scheme (MCS) can be computed with low complexity in latter cases.

v. **Adaptive Beamforming[56]:** For a MIMO transceiver system, adaptive beamforming can significantly improve the coverage and throughput. New beamforming algorithms can be created along with improvement of existing algorithms by using computer vision and adaptive machine learning based algorithms. Generative adversarial networks (GAN) can help by predicting the next beamforming directions based on the inputs from the previous directions by analyzing the locations of the mobile devices. Rotating the antennae or using previously placed ones, based on the estimated new location of the targeted device, signals can be transmitted and received in a directed way.

vi. In Nov 2020, Networking and Information Technology Research and Development (NITRD) published a report[57] in which NITRD highlighted potential uses of AI in spectrum management which include Spectrum monitoring, Spectrum diagnosis, Mitigation of interference, Network integration and Spectrum sensing.

vii. Following are some International Practises where AI/ML is implemented for spectrum management:

   a. Finland[58], is actively bringing AI into spectrum management with automated, adaptive systems that handle parts of spectrum allocation management, including planning, sharing, authorization, monitoring, and pricing.

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56 https://ieeexplore.ieee.org/document/9322515
57 https://www.nitrd.gov/pubs/AI-WirelessSpectrum-2019WorkshopReport.pdf
58 https://www.bcg.com/publications/2020/coming-battle-for-spectrum

b. The National Institute of Science and Technology (NIST)[59] in the US has been testing deep-learning algorithms for spectrum sharing that allocate band usage on the fly among military and commercial users.

viii. In table 3.3, a list of various applications of AI in spectrum management, currently being used by global operators.

3.2.3. **Network Security**

i. As the world enters the era of smart society, ICT infrastructure will become ubiquitous and bear key responsibility of supporting industry digital transformation. Within these smart societies, a large number of IoT devices, smartphones, and other devices are connected to each other either through a public network or through a private secured network.

Table 3.3:   Lists of various applications of AI in spectrum management.

Spectrum Allocation and Sharing	Spectrum Optimisation & Configuration	Spectrum Monitoring
- Spectrum Sensing - Signal Classification - Dynamic Spectrum Access - Channel Selection - Dynamic allocation/ Network Slicing	- Configuration of Femtocells - Load balancing - Cell splitting /merging - Enhanced carrier aggregation	- Spectrum Demand prediction - Channel Estimation

The exponential growth in the number of these devices in recent years has led to a significant growth of cyber-attack incidents often with disastrous and grievous consequences. Though in industry, there exists a variety of solutions to protect the network and devices from these attacks, yet most of these solutions are static in nature and behave in a reactive manner, which may not be efficient to counter attacks proactively. At the same time techniques of adversaries are also evolving rapidly, and therefore variety of advanced and unknown threats targeting networks and devices are ever

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59 https://www.bcg.com/publications/2020/coming-battle-for-spectrum

expanding. To mitigate such threats, existing solutions may not be effective and there may be requirement of innovative technologies which behave intelligently to protect the network and connected devices in advance.

ii. Here, AI can play the role of critical technologies in analysis of millions of events and identify possible threats, from malware exploiting zero-day vulnerabilities to identifying risky behaviour which may lead to a phishing attack or download of malicious code. These technologies learn over time, drawing information from the past to identify new types of attacks now.

iii. Use cases of AI for securing telecom networks are listed in table 3.4 and a few of them are discussed below:

a. **Anomaly detection in the network:** Anomaly detection is a task of identifying instances whose behaviour differ significantly from normal and/or expected behaviour in the data. The importance of anomaly detection can be seen in identification of faults or failures in the systems. Anomaly detection has been applied in a variety of ways in the field of telecommunications. The analysis of KPIs based on network nodes performance data requires analysis of voluminous data which is practically not feasible through manual processes and therefore experts resolve problems through simulation and predictive data analysis. AI facilitates automatic analysis of thousands of network elements with hundreds of their behavioural and contextual features reflected in KPIs, which helps in identifying network nodes with deviant behaviour in quick time frame. AI based anomaly detection helps experts to become proactive in their ability to identify service degradations and outages by providing dynamic monitoring, real-time analysis, and by correlating between metrics across network layers, applications, databases, storage, CRMs etc. The Ericsson on its website[60] also shows how to build robust anomaly detectors with ML.

The following example illustrates how AI helps in anomaly detection.

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[60] https://www.ericsson.com/en/blog/2020/4/anomaly-detection-with-machine-learning

Suppose AI is being deployed in the telecom network which is continuously monitoring the behaviour of the network parameters. Let at an instance, one of the network nodes is affected by any reason and the network parameters of that node start affecting functioning of the connected devices, the AI system so deployed observed this behaviour and tries to correct the affected parameters by integrating additional values to the parameters to compensate the damage. In this case AI decides such additional values based on the learnings of incidents similar to the current one. AI also informs the service provider regarding such incident and also proposes the corrective measures to resolve the issue in affected node. A whitepaper by 5G Americas[61] states that ML algorithms can identify and predict faults or performance degradation, isolate and remedy them. Replacing manual tasks with automation aided by Analytics using Smart Databases, Artificial Intelligence (AI) and Machine Learning (ML) systems will help maintain the required network low latencies and reliability and will significantly reduce the Service Assurance (fault detection, Root cause Analysis and correction) turnaround time.

b. **Adaptive securit**y[62]: Adaptive security studies patterns and behaviours rather than just examining log files, monitoring checkpoints and responding to alerts. It provides real-time network security monitoring that analyses the network for anomalies, malicious traffic, and vulnerabilities. If any threat is detected, the platform automatically implements security measures that counter the threat in a number of ways. Gartner[63] lists the four stages of an adaptive security as: predict, prevent, respond and defect. These can be briefly defined as:

- Predict – assess risk, anticipate attacks and malware, implement baseline systems and posture.

61   https://www.5gamericas.org/wp-content/uploads/2019/11/Management-Orchestration-and-Automation_clean.pdf

62   https://www.sumanastech.com/what-is-adaptive-security-architecture-and-how-it-will-protect-your-business/

63   https://www.gartner.com/smarterwithgartner/build-adaptive-security-architecture-into-your-organization

- Prevent – harden and isolate systems to prevent security breaches.
- Respond – investigate incidents, design policy changes, conduct retrospective analysis.
- Defect – prioritise risks, defects and contain incidents.

These four stages, combined with policy and compliance measures, are used to create a system with an ability to quickly trace and respond to suspect behaviour at the source. This happens with situations such as malware connecting at an endpoint, or a user acting suspiciously. These capabilities of AI may further improve adaptive security applications.

Without AI systems, the operator is manually monitoring each and every node in a predefined sequence to observe any risk/attack on the system. Manually analysing each threat and predicting the best resolution may be a difficult task in real time. With AI, network can monitor and protect in real time. With AI, network may learn from the data and decide the most appropriate sequence to monitor network nodes instead of any predefined sequence. AI can also dynamically predict the threats and adapt the network to resolve each threat.

Table 3.4:   Lists of various applications of AI for network security.

Detection	Prevention	Prediction
• Threat/Anomaly Detection • Malicious Code Detection • Fraud detection • Detection of illegal use of SIM Box • Combating use of Counterfeit ICT Device	• DDoS Prevention • Fraud Prevention • Adaptive security • Active Defence • Threat Hunting	• Fault Prediction

iv.   As per the information published on their website and the report on "AI in

Telecom Operations: Opportunities & Obstacles[64]" published by Heavy Reading, operators in other jurisdictions are using AI to secure their networks and operations. Some examples of these use cases are, fighting fraud by AT&T, Fault Prediction by Colt, AI-based monitoring system (Advance detection of fatal situations) by KDDI and Security and anti-fraud solution based on AI by Orange etc. In India too, operators are using AI for real time anomaly detection in the network.

3.2.4. Customer Centric

i. The use of artificial intelligence as a means of determining and driving customer experience will take a great leap forward, helping telcos to better understand and serve their customers. AI will bring together behavioural and conventional system-sourced data, location tracking, social media monitoring and other sources, to contextualise and personalise customer experience in the real and online domains. These technologies will help operators develop empathetic marketing and target customers more precisely with personalised offers and services, creating new sales opportunities.

ii. **Virtual assistants** are being deployed across the globe by most of the organisations to engage their users and serve customers by catering to their queries to improve customer experience. There are simulations which can understand human language, process it and interact back with humans while performing specific tasks. AI makes it possible for chatbots to "learn" by discovering patterns in data. AI-powered chatbots which are a type of virtual assistants can save businesses money while allowing customers to take care of minor issues on their own time. The telcos and other industries are currently using AI to improve the customer experience by employing chatbots, which enables virtual assistance for selecting voice or data packs, troubleshooting, answering FAQs, and personalised interaction etc. TOBi[65], is a Vodafone's friendly digital assistant

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64 http://www.heavyreading.com/details.asp?sku_id=3558&skuitem_itemid=1781

65 https://www.vodafone.co.uk/help-and-information/introducing-tobi

launched in the United Kingdom. It provides 24/7 support, saves time and provide personalised information almost instantly without hanging about on hold, and hand over to a real-life, human adviser in case it cannot help at any time. Similarly, Airtel's "Callup"[66] AI is a chat and voice assistant that uses the power of AI to quickly and effectively resolve customer queries over email, chat and phone calls in vernacular languages.

iii. **AI to assist customers in choosing tariff plan:** Currently, telcos offer variety of tariff plans and vouchers. Customers sometimes find it very difficult to choose best plan for them. AI may help customers to compare different plans in a more relevant way by considering customer specific consumption patterns. Such AI based applications might be offered by third parties as tariff plans are available in public domain and consumption pattern can be made available by the app installed on the device for this specific purpose. AI may also help telecom service providers to design new tariff plans considering the requirements of customers. Ai can be used for selection of variety of options in other sectors including broadcasting also.

iv. As per the report on "AI in Telecom Operations: Opportunities & Obstacles" published by Heavy Reading, operators like AT&T, Colt, Globe Telecom have implemented digital assistant tools for customers; and Deutsche Telekom (Europe) deployed chatbots for recruitment process and for supporting the service team.

v. Customer segmentation, Customer sentiment analysis and Price optimization are a few more applications of AI for improving customer experience and services in the telecom sector.

3.2.5. **Broadcasting sector**

The use of AI in the media and entertainment industry is helping them to improve their services and enhance the customer experience.

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[66] https://www.airtel.in/press-release/10-2018/airtel-strengthens-artificial-intelligence-portfolio

Here are a few use cases[67] of AI in media and entertainment industry:

i. **Metadata tagging:** With countless pieces of content being created every minute, classifying these items and making them easy to search for viewers becomes a herculean task for media companies. That is because this process requires watching videos, identifying objects, scenes, or locations in the video classifying them appropriately and add tags.

   To perform this task on a large scale, AI may be used to analyze the contents of videos frame by frame and identify objects to add appropriate tags. AI tools identify the objects and scenes in images that are specific to the business needs. This mechanism is termed as metadata tagging. This technology is being used by content creators or media publishing, hosting, and broadcasting platforms to organize their media assets in a highly structured and precise manner. As a result, regardless of its volume, all the content owned by media companies becomes easily discoverable.

ii. **Content personalization:** Leading music and video streaming platforms like Spotify and Netflix are successful because they offer content to people belonging to all demographies, having different tastes and preferences. These companies use AI and ML to share personalized recommendations. Such companies are using AI and ML algorithms to study individual user behaviour and demographics to recommend what they may be most interested in watching or listening, and suggesting next content and thereby keep them constantly engaged. As a result, these AI-based platforms are providing customers with content that caters to their specific interests, thus offering them a highly personalized experience.

iii. **Reporting automation:** In addition to automating day-to-day or minute-by-minute operations, AI is also helping media companies to make strategic decisions. For instance, leading media and

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[67] https://phrazor.ai/blog/applications-of-ai-in-the-media-entertainment-industry

broadcasting companies are using AI to create channel performance reports from raw analytics data shared by Broadcast Audience Research Council of India (BARC). The weekly data usually received from the BARC is generally in the form of voluminous Excel sheets. Analysing these sheets on a weekly basis to derive and implement meaningful learnings proves to be quite daunting for the analytics team. By using AI-enabled data analysis and natural language generation-based reporting automation tools, business leaders can create performance reports with easy-to-understand analysis, providing them accurate insights to make informed data-driven decisions.

iv. **Subtitle generation**: International media publishing companies need to make their content fit for consumption by audiences belonging to multiple regions. To do so, they need to provide accurate multilingual subtitles for their video content. Manually writing subtitles for multiple shows and movies in dozens of languages may take hundreds or even thousands of hours for human translators. Today, most of the content platforms such as YouTube, Spotify, and Instagram and others allow publishers to add automatic transcription to their videos. Without AI algorithms, it may be difficult to find the right human resources to translate content for certain languages. Additionally, human translation can also be prone to errors. To overcome these challenges, media companies are leveraging AI techniques such as natural language processing and natural language generation for subtitle generation. For example, YouTube's AI allows its publishers to automatically generate closed captions for videos uploaded on the platform, making their content easily accessible.

3.2.6. **Other areas in telecom**

i. **Churn prediction:** In the Telecommunication Industry, customer churn detection is one of the most important research topics that the company has to deal with for retaining on-hand customers. Churn

means loss of customers due to exciting offers of the competitors or maybe due to network issues. In these situations, customers may tend to cancel the subscription to a service. Churn rate has a substantial impact on the lifetime value of the customer because it affects future revenue of the company and also length of service. Due to a direct impact on income of the industry, the companies are looking for a model that can predict customer churn. So, one way to reduce churn is to understand exactly what kinds of events cause customers to be unhappy enough to leave:

a. Is dropped call a primary issue? If so, then how frequently does it occur and within what time-period?
b. Do slow video visualisations cause by traffic overload trigger churn?
c. What about SMS delivery issues?

Leveraging ML in more advanced churn prediction[68] reveals not only about the most likely churners, but taking it one step further, to activate marketing teams to respond positively through marketing methodologies (known as uplift modelling).

ii. **Spam:** As mentioned in Telecom Commercial Communications Customers' Preference Regulations 2018 (TCCCPR 2018)[69], AI/ML may be used in the Unsolicited Commercial Communication (UCC) Detect System. The TCCCPR 2018 highlighted that to deal with UCC from Unregistered Tele-Marketers (UTM), signature solutions need to be enhanced which shall be referred to as the UCC Detect System. While determining whether a person or entity is suspected sender of UCC, this system may include additional sources of inputs such as sending information (SI) from reports, inputs collected from Honeypots, information shared by Signature Solutions of other access providers and information available from network elements (examples of which are HLR, and Missed Call Alerts). Such a system

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[68] https://pages.dataiku.com/churn-prediction?instantmag-attribution-guidebook%0D
[69] https://trai.gov.in/sites/default/files/RegulationUcc19072018.pdf

would be able to identify suspected UTMs with greater accuracy when it is equipped with more information about suspected UCC senders. Technology based solutions can be designed to carry out all these checks and retrieve desired information in a short time. This system may also use Artificial Intelligence (AI) and Machine Learning (ML) techniques to constantly evolve to deal with new signatures, patterns and techniques used by UTM for sending UCC and while remaining undetected.

Further, AI may also be implemented to curb UCC by adopting AI in UCC detect system, smart preference management, smart complaint handling, smart consent acquisition and revocation, smart content template verification and management, and header allocation process.

iii. Telcos will also have more advanced tools at their disposal to reduce frauds by applying AI to usage/location analysis of devices and services. In particular, operators will be able to uncover and halt roaming and SIM-based frauds for subscription services. In the pre-paid domain, AI will help detect abnormal accumulation of credit, top-ups based on stolen codes, and more.

3.2.7. The above sections emphasis that there are vast opportunities of AI in improving QoS, spectrum management, security, customer services, broadcasting and much more in the telecom sector. According to GSMA[70] report on use cases of AI in telecom, various use cases are in development phase or at trial or pilot phase or are already deployed in the telecom network as shown in figure 3.1. This shows that in coming years, AI may open up new opportunities in the telecom sector. Also, with AI, and other technologies such as SDN, NFV, cloud and edge computing, the telecom network has already transformed to intelligent network and will further improve in future. These transformations in telecom network may further support adoption of AI and also open up

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[70] https://www.gsma.com/futurenetworks/wiki/ai-automation-an-overview/

new services or opportunities for other sectors. The following sections discuss what are the key offerings for other sectors in adoption of AI.

3.3. Opportunities for Others: *Telecom beyond Connectivity*

3.3.1. Traditionally role of telecom network was to provide connectivity between two or more points through circuit switching methodologies. Later packet switching based telecom network routed the data packets from a client to a host of applications. Intelligence used to lie at the end points. With the evolution of telecom networks, intelligence has been built across all elements in the network of a telecom system.

Figure 3.1:   AI in networks: status of deployment of applications (not exhaustive)
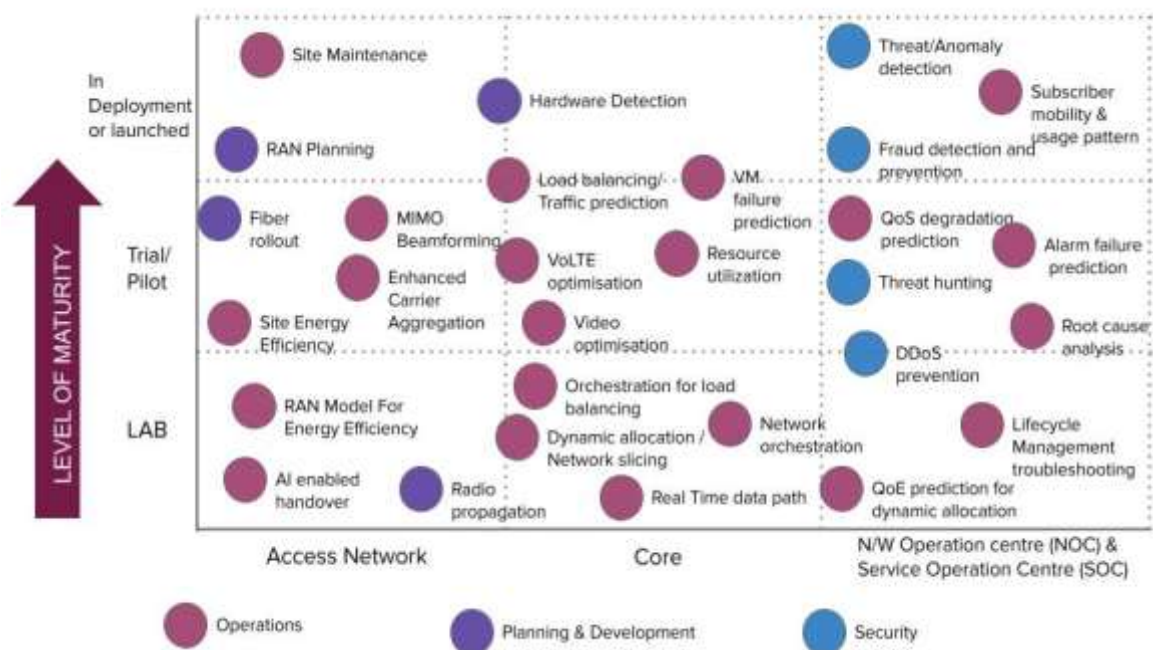
3.3.2. In the last few years, by adding more layers in the network, telecommunications have clearly moved beyond providing people to people connectivity. With the advancements in technologies such as SDN, NFV, AI, ML and Cloud Services, the network has gained additional capabilities of intelligence for gainful utilization of network resources beyond connectivity. Today, adoption of SDN and NFV in the networks makes it programmable for any function based on the requirements for

any specific purpose in an area without upgrading the hardware capabilities.

3.3.3.   With the adoption of AI, telecom networks can learn from their past experience and can forecast the behaviour of the network for catering futuristic requirements. The network can also behave proactively to detect any threats on the systems and secure its operations on its own. AI has evolved the network into an intelligence pipeline which may play a key role in other sectors.

3.3.4.   Further, advancements in computation technologies such as Cloud Computing, Edge Computing help data payloads processing in distributed manner at the edges. This functionality removes the hindrance of moving data from device to central node for processing and re-routing to the destination nodes. Now, the devices are self-sufficient to process any data at edge without sharing or with minimal sharing of information. This enhancement in computations not only solves the concern related to data sharing to central nodes but also reduces the latency of the network and improves the accessibility to services.

3.3.5.   The ITU describes an architectural framework[71] for networks to accommodate current as well as future use cases of Machine Learning. It offers a common vocabulary and nomenclature for Machine Learning functionalities and their relationships with ICT networks, providing for 'Machine Learning Overlays' to underlying technology-specific networks such as 5G networks. The components of the architectural framework include:

i.   Machine Learning Pipelines: Sets of logical nodes combined to form a Machine Learning application

ii.   Machine Learning Function Orchestrator: To manage and orchestrate the nodes of the pipelines.

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[71] https://www.itu.int/rec/T-REC-Y.3172-201906-I/en

iii. Machine Learning Sandboxes: Key component of the framework, offering isolated environments hosting separate Machine learning pipelines to train, test and evaluate ML applications before deploying them in a live network.

iv. Developing a standard way for different parties to look at the intelligence level of the network helps operators to evaluate vendors and regulatory authorities to evaluate the network.

v. The series of ITU standards also discusses the interoperability of Machine Learning marketplaces, marketplaces hosting repositories of Machine Learning models.

3.3.6. The future network is being designed to leverage emerging technologies. Thus, the capabilities which move networks to work beyond connectivity may play a key role in facilitating other sectors for adoption of the AI.

3.3.7. **What telecom can offer to others?**

i. **Access to Data/Insights:**

a. The telecommunications industry generates and stores tremendous amount of data in terms of call data records and network data. It also comprises of data in respect of state of the hardware and software components in the network, customer profile and commercial usage data. With the increasing adoption of smartphones and growth in mobile internet, telcos today have access to exceptional amounts of data sources including mobility and device data, customer usage patterns and location data.

b. Data which is available or might be available with the TSPs may be quite useful to provide insights to others to carry out their forecasts, planning, designs, operations and maintenance. These data sets can be utilised for various analytical services and representations. The following are few instances where telecom data or insights from this data may be useful for others:

- A restaurant in a suburb of Mumbai would value knowing the population density within a specific geo-radius during specific time intervals. The restaurant management can utilise this information to efficiently manage staff and adjust operating hours accordingly.

- Accessed data from device sensors such as GPS, Wi-Fi, Bluetooth, accelerometer records usage patterns and context in which it is being used. Once this data is converted into a user profile information, it can be utilised in many novel ways in consideration with usage context. Let us understand this with an example of transportation department which can use the mobility data of the customers of the TSPs to predict the traffic flow in each area by considering the past mobility history of telecom customers. And with support from AI system, traffic lights and traffic movement can be intelligently managed.

- Similarly, telecom sector can help finance sector to predict the customers vulnerable to frauds or other financial attacks. The telcos can prepare a repository of data related to financial frauds for example, location of call/message initiated for the fraud, duration of call/message from that location, intensity of call/message from that location, etc. This data may be fed to AI/ML models of banks to predict vulnerable customers.

c. In the upcoming times, various other data types such as meta data, insights of data might be available in telecoms' network. Such datasets from traffic carried by telecom network could be leveraged for other purposes. To gather such datasets related to sector specific applications whose traffic is passing through telco's network there may be requirements to have relevant information elements in standard network protocols. In addition to it, there might be some proxy parameters which may give some indications

for example, Netflix traffic or gaming traffic or V2X traffic in a locality. Insights from these metadata help in understanding user's behaviour. Using AI and BD tools, context of an individual may be determined. Consider a scenario where a food delivery service might know eating preferences of a certain user, whereas an online streaming service might know watching pattern, however each entity has a limited perspective of the user. On the other hand, telcos can understand its subscriber in a comprehensive manner using the metadata from traffic and other telecom data. Perhaps telecom networks, being an application-level bridge, may play the role of an orchestrator or federate as it might be in a best position to determine the context of an individual. It might enable execution of contracts after determining the context of an individual in a multi-sector, multi-domain environment.

d. Following are some examples where telecom data is already being used by other sectors to their services or operations:

- A report on "*Utilising Mobile Big Data (MBD) and AI to Benefit Society*" was published by GSMA. The report highlights a list of countries using MBD analytics applications to support the Covid-19 response. During the crisis, the potential of mobile data and telecom was realised. Institutions and governments started to explore how mobile big data solutions could help track, contain and predict the spread of the virus. By utilising Mobile Network Operator (MNO) data along with health data and GIS information, the potential use cases are, population mapping for population density and location, population mobility to monitor compliance with lockdown measures and movement patterns, epidemiological modelling for spread of disease, logistics and infrastructure monitoring and economic monitoring to study impact of lockdown etc.

- **Case *study: Data for social good - COVID-19 Pandemic:***

When India was at the cusp of the first wave of COVID-19 in April 2020, Telecom operators stepped forward to support the government in identifying potential customers and locations at risk of infection. In the virtual conference, Airtel discussed the analysis framework to identify potential carriers, hotspots with high mobility and also the reverse migration of people. The model is primarily fed with Call history data through CDR and geo-tagging data (GIS). Additionally active locations from Applications and Bluetooth based proximity data from handset was also used to identify covid-19 infected persons and perform contact tracing. Monitoring compliance with lockdown enforcements also helps in containing the spread. Subscriber's location using CDR was analysed to determine reverse migration and build epidemiological models for future hotspots. Utilising mobile big data and AI, habitual movement patterns were determined and this information was used to minimise the risk of re-emergence of COVID-19 in post lockdown period.

e. Thus, other sectors/players may utilise the data or insights of data available with telecom operators for their benefits.

ii. **Execution Environment to Test/Demonstrate/Run AI models:**

The capabilities of telecom networks to compute and process data at the edge in distributed manner may be helpful for others in monitoring and managing their resources effectively and efficiently and creating new opportunities, if any. Here, other sectors may utilise the telecom infrastructure for storage, computation, testing AI etc. The distributed computation at the edge may not only provide an execution environment but also provide privacy to the users by integrating technologies like Federated Learning. The following are some case scenarios, which describes how telecom infrastructure can be utilised by other sectors for their benefits:

a. **To test or demonstrate AI models:** The telecom sector may

provide environment to test or demonstrate AI models. In the AI ecosystem, there are players such as solution providers, researchers, and individuals etc. who are interested in developing solutions for the telecom industry or for some other sectors, however, building an environment to test or demonstrate their solutions would cost them higher than overall cost of their project. Further, there may exist some players who have developed a solution limited to small network. However, to build a robust solution there may be requirement of testing in real environment. In these cases, the TSPs can offer their network to test or demonstrate the AI solutions developed by other players.

b. **To run AI models:**

- A farmer desires to improve the productivity of his fields by using IoT devices. This requires real-time monitoring and optimisation of their fields from every perspective such as quality of soil, quality of seeds, growth pattern of plants, water content in soil etc. For this, data from IoT devices, duly connected with service and application providers can be analysed to predict and implement the necessary operations. The service providers may use a combination of technologies like federated learning and edge computing to offer an execution environment to the farmer. The IoT devices so connected, will provide the necessary data to the telecom network at the edge where the model will be trained and executed. Based on the outcomes of the models, IoT devices may be managed intelligently to improve the overall productivity of the fields through say timely sowing or irrigation or use of right kind of fertilizers etc. in the fields.

- Let us take another example of the transportation sector. Transportation sector with data mapped with AI/ML model can manage traffic centrally and intelligently in the city. The

telecom network deployed for connecting various IoT devices/sensors may use a combination of edge computing and federated learning to train models and act at node to manage the traffic lights.

- The remote working culture has been adopted by many organisations and interacting through video conferencing is a new paradigm. In video conferencing, recent update brought background-change functionality which works on RGB-D (Red Green Blue-Depth) segmentation, where the foreground is segmented from the background and new background is inserted, which happens in real time conditions. However, sometimes we see lagging and inefficient segmentation. This is because the process is computationally heavy. Here telecom can assist by providing processing at the edge and running the algorithm near to the user to bring a rich experience.

- In a similar way, telecom networks may provide an execution environment in leveraging AI/ML in various other sectors.

There may exist multiple such offerings where telcos offer other services beyond connectivity.

Issues for consultation

Q.5. Which are the applications of AI and BD already being used by the TSPs in their networks to improve Quality of Service, Traffic Management, Spectrum Management and for Security purposes? Please list out all such applications along with the level of maturity of such applications. Please specify whether they are at trial stage or pilot stage or have reached the deployment stage? Details should include type of AI models, methods to access data, and procedures to ensure quality of data.

Q.6. **What are the major challenges faced by the telecom industry, including policy and regulatory, in developing, deploying, and scaling applications of AI listed in the response to Q.5? How can such challenges be overcome? Please justify your response with rationale and suitable examples, if any.**

Q.7. **In which areas of other sectors including broadcasting, existing and future capabilities of the telecom networks can be used to leverage AI and BD? Please justify your response with rationale and suitable examples if any.**

3.4. Emerging risks from the use of AI and BD

3.4.1. AI and BD have vast opportunities to enhance services for consumers, improve the performance of the network, and prevent harm from malwares etc. New technologies such as AI and BD not only provide new opportunities but also bring large risks. Such risks span the entire life of an AI solution, from its conception to usages and monitoring which may result into unintended consequences. The risks include unethical use cases, insufficient learning from feedback loop, implementation errors, biased or discriminatory model outcomes, model instability or performance degradation, insufficient training, regulatory non-compliance etc. Out of these, some of the risks are sector agnostic and some are sector specific, as discussed in detail in following sections.

3.4.2. **Sector Agnostic risks**

i. **Data**

The data used for training models of AI may pose certain risks. Few of them are listed below:

a. **Low Quality Data:** The low-quality data can lead to poor predictions and biases. Data can be either poorly selected or incomplete, incorrect, or outdated. Poorly selected data might

include 'unrepresentative data', which do not allow generalising about other groups. For example, if an AI model was created using data on people of age 30 to 40 for selecting tariff plans, then the predictions for people of age 20 to 30 and more than 40, might not hold true.

b. **Data Biases:** If data used for building an AI model is biased against a group, the model will replicate the human bias in selecting them and learn to bias against that group. Data can be biased for several reasons, including the subjective choices made when selecting, collecting and processing the data. For example, with the dream of automating the recruiting process, Amazon started an AI project[72] in 2014, but same could not continue beyond 2015 as the data used for model training was biased. Therefore, the AI model did not present clear rating based on analysis of applicants' resumes. Further, biases in data[73] can exist in many shapes and forms, some of which can lead to unfairness in different downstream learning tasks.

c. **Data Security:** New AI models have complex, evolving vulnerabilities that create both novel and familiar risks. Vulnerabilities such as model extraction and data poisoning can pose new challenges to long-standing security approaches. In case of data poisoning, the attackers may affect AI model training by data injection, deletion, or manipulation so that the model learns incorrect biases and cannot serve its intended purpose. Meddling with even a single data point can cause the ML model to underperform significantly. A bad actor may therefore use data poisoning to undermine AI-powered identification of money laundering operations or create a ransomware that impairs the smooth operation of an agency. A terrorist could also feed poisoned data into AI systems that control air traffic or classify

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[72] https://research.aimultiple.com/ai-bias/
[73] https://arxiv.org/pdf/1908.09635.pdf

friendly and hostile military vehicles.

d. **Data Privacy:** Unprotected data without proper encryption used for training models may raise concern of privacy of the individuals. These characteristics of AI enable it to affect privacy in a number of different ways[74]:

- **Identification and Tracking:** AI can be utilised to identify, track and monitor individuals across multiple devices, whether they are at work, at home, or at a public location. This means that even if your personal data is anonymized once it becomes a part of a large data set, an AI can de-anonymize this data based on inferences from other devices.

- **Profiling:** AI is not just limited to performing information gathering tasks. It can also use data as input for the purpose of sorting, scoring, classifying, evaluating and ranking people. This is often done without any consent on the part of the people being categorised, and they often have no ability to affect or challenge the outcomes of these tasks. China's social scoring system is an example of how this information can be used to limit access to things like credit, employment, housing or social services.

ii. Model

The training models may also pose risks as listed below:

a. **Training on non-represented data:** The models trained on non-representative data, may pose risks for those whose data is not considered for training models. For example, a city distribution map is being prepared by using the telecom data, and the model only considers the data of only one TSP. This may not properly represent the correct picture of the city as there may exist multiple operators in a city.

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[74] https://towardsdatascience.com/ai-and-the-future-of-privacy-3d5f6552a7c4

b. **Inaccuracy Algorithm:** Incorrect type of algorithm(s) applied to a problem, poor data quality or suboptimal choice of algorithm parameters.

c. **Biased Algorithm:** A biased algorithm tends to systematically learn the wrong signals by not considering all the information contained within the data. Model bias may lead an algorithm to miss the relevant relationship between data inputs (features) and targeted outputs (predictions). In essence, bias arises when an algorithm has insufficient capability in learning the appropriate signal from the dataset. For decades, bias in machine learning has been recognized as a potential concern, but it remains a complex and challenging issue for machine learning researchers and engineers when deploying models into production. The COMPASS (Correctional Offender Management Profiling for Alternative Sanctions) algorithm[75], which is utilised in US court systems to estimate the probability that a defendant will be a reoffender, is the most prominent example of AI bias and the negative implications on the society. The algorithm predicts twice as many false positives for recidivism for black offenders (45%) than for white offenders (23%), and 77% more likely to peg black offenders as high risk of committing violent crimes in the future while mis-labelling white offenders as low risk.

d. **Model instability or performance degradation:** AI applications, if not implemented and tested properly, can suffer performance issues that breach contractual guarantees and, in extreme cases, pose threats to personal safety. Suppose a model is used to ensure timely updates of machinery in manufacturing or mining, a failure of this model could constitute negligence under a contract and/or lead to employee harm.

iii. **Model use and decision making:** A lack of transparency around how a model was developed (such as how data sets feeding into a model

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[75] https://arize.com/blog/understanding-bias-in-ml-models/

were combined) or the inability to explain how a model arrived at a particular result can lead to issues which may run into legal hurdles. For example, if a consumer initiates an inquiry into how his or her data was used, the organization using the data will need to know into which models the data was fed.

iv. **Unethical use of AI**

A European Parliament study paper[76] states that ethics are moral principles that govern a person's behaviour or the conduct of an activity. The organisations may be worried about the unethical use of AI or unethical learning of AI models. AI ethics is concerned with the important question of how human developers, manufacturers and operators should behave in order to minimise the ethical harms that can arise from AI a in society which either arising from poor (unethical) design, inappropriate application or misuse. The scope of AI ethics spans immediate, here-and-now concerns about, for instance, data privacy and bias in current AI systems, near and medium-term concerns about, for instance, the impact of AI on jobs and the workplace and longer-term concerns about the possibility of AI systems reaching or exceeding human-equivalent capabilities. The chapter 2 of the study paper highlights main ethical issues associated with the development and implementation of AI which include impact on society, human psychology, trust, financial system, legal system and on environment.

v. **Reputation risk:** Data is the lifeblood of any AI model. Privacy laws around the world mandate how companies may (and may not) use data, while consumer expectations set normative standards. Running afoul of these laws and norms can result in significant liability, as well as harm to consumers. Violating consumer trust, even if the data use was technically lawful, can also lead to reputation risk and a decrease in customer loyalty.

76
https://www.europarl.europa.eu/RegData/etudes/STUD/2020/634452/EPRS_STU(2020)634452_EN.pdf

> **vi. Other risks:** Also, the operators may have other risks such as loss of direct control, risks in return of investments, etc.

3.4.3. Sector specific

> **i. Regulatory Non-Compliance:**
>
> Management may face difficulty in understanding and justifying decisions made in complex AI applications, such as those decisions made using neural networks consisting of a number of hidden decision-making layers. This may create non-compliance with regulatory norms as they are unaware about the impacts of these technologies in future. This is because decision making would then depend on network requirements and not on customer needs. Improvement of performance of the network might pose risks of non-compliance from the regulator perspective as the system might fail to show improvement in Key Performance Indicators (KPIs) defined by the regulator. The issue may be due to static and obsolete KPIs which require reform with new developments, else it may hamper growth in the sector.

> **ii. Legal Non-compliance:** Industries, sectors, and regions around the world have varying standards and laws regarding privacy, fairness, and other risks presented in this framework. Building any AI system without the knowledge of related laws may affect the application areas of the AI systems. Therefore, it's important to be aware of applicable laws and regulations based on where, how, and in what sector the model will be deployed.

3.4.4. Risks to Market & Suppliers

Deloitte[77] in its report highlighted following risks associated with AI and Big Data:

> **i. Market**

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[77] https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/innovatie/deloitte-nl-innovate-lu-ai-and-risk-management.pdf

a. Over-reliance in the market on a relatively small number of large third-party AI vendors increases concentration risk and may have network effects in the event that one of these entities becomes insolvent or suffers a significant operational loss.

b. Increased systemic risk resulting from herding behaviour (i.e. organisations acting identically to other market participants), if algorithms are overly sensitive to certain variables (e.g. stock market prices).

ii. Supplier

a. Use of "black box" algorithms may result in a lack of clarity around allocation of liability between vendors, operators and users of AI in the event of damages.

b. Increased risk of AI third-party providers' failure, especially in the case of new and smaller players. For example, organizations may outsource data collection, model selection, or deployment environments. The organization engaging third parties must know and understand the risk-mitigation and governance standards applied by each third party, and it should independently test and audit all high-stakes inputs.

3.5. Ways and mechanisms to mitigate risks

3.5.1. There is a need to establish mechanisms to mitigate risks in developing and adoption of AI solutions. The risks which are sector agnostic may be dealt under the common regulatory framework while in case of sector specific risks, respective sector regulator may be required to develop a specific framework. Globally, various countries have adopted approaches and initiatives towards developing more responsible and trustworthy AI systems. India has also taken few initiatives on similar lines. Some of the key initiatives are mentioned below:

i. High-Level Expert Group on Artificial Intelligence (AI-HLEG) was set up by the European Commission in June 2018, as part of the AI strategy. The High-Level Expert Group on Artificial Intelligence prepare a document titled "The Ethics Guidelines for Trustworthy Artificial

Intelligence[78] (AI)". The document highlighted that Trustworthy AI has three components, which should be met throughout the system's entire life cycle: (1) it should be lawful, complying with all applicable laws and regulations (2) it should be ethical, ensuring adherence to ethical principles and values and (3) it should be robust, both from a technical and social perspective since, even with good intentions, AI systems can cause unintentional harm. Each component in itself is necessary but not sufficient for the achievement of Trustworthy AI. Ideally, all three components work in harmony and overlap in their operation.

ii.   In February 2020, the EU published a whitepaper on Artificial Intelligence - *A European approach to excellence and trust[79]*. Under this, the Commission published seven key requirements identified in the Guidelines on trustworthy AI, fairness, accountability, societal and environmental wellbeing for AI systems in order to be deemed trustworthy. Similar to the European commission, countries like United Kingdom[80], Australia[81], United Arab Emirates [82] , China[83] etc. have also formulated guidelines for responsible AI.

iii. Realizing its importance, many countries and even enterprises have adopted ethical principles. It is observed that some countries have formulated principles specific to the nation's requirements, some have collaborated with other countries to adopt common guidelines, and many private organizations have formed advisory councils on ethical matters and even formulated principles for responsible AI. Some of them are mentioned below:

a. As discussed above, European Union identified seven key

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[78] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=60419

[79] https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

[80] https://www.gov.uk/guidance/understanding-artificial-intelligence-ethics-and-safety#contents

[81] https://www.industry.gov.au/data-and-publications/australias-artificial-intelligence-ethics-framework/australias-ai-ethics-principles

[82] https://www.smartdubai.ae/initiatives/ai-principles-ethics

[83] https://www.wired.com/beyond-the-beyond/2019/06/beijing-artificial-intelligence-principles/#:~:text=Human%20privacy%2C%20dignity%2C%20freedom%2C,utilize%20or%20harm%20human%20beings.

requirements for achieving trustworthy AI. Similarly, Australia's Department of Industry, Science, Energy and Resource developed an AI Ethics Framework[84] to guide businesses and governments looking to design, develop and implement AI in Australia. Many other nations like, United states, Singapore[85], Rome[86], etc. have stepped forward to foster adoption of ethical systems and to present the need for trustworthy AI systems.

b. Further, member countries of OECD such as Austria, Belgium, and Czech Republic adopted OECD Principles on Artificial Intelligence[87] in May 2019. Beyond OECD members, other countries[88] including Argentina, Brazil, Costa Rica, and Romania etc. have also adhered to these AI Principles.

c. Apart from the national and global level, initiatives at individual level can also be observed. From tech-companies to representatives of civil society, to academic and research institutions, to start-ups and beyond, many have joined hands to bring a positive impact of AI on society. For instance, Microsoft has its own AI advisory board[89] and Google disclosed its AI principles[90], an ethics charter to guide the responsible development and use of AI in research and products. Collaborative industry groups, such as the Partnership on AI[91] (including Microsoft, Amazon, Facebook and Apple), have pledged to develop and share best practices, including on ethics.

iv. In India, NITI Aayog published principles of responsible AI in "*Approach Document for India Part 1 – Principles for Responsible AI*"[92]

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84 https://www.industry.gov.au/data-and-publications/building-australias-artificial-intelligence-capability/ai-ethics-framework/ai-ethics-principles

85 https://www.pdpc.gov.sg/Help-and-Resources/2020/01/Model-AI-Governance-Framework

86 https://www.romecall.org/

87 https://www.oecd.org/going-digital/forty-two-countries-adopt-new-oecd-principles-on-artificial-intelligence.htm

88 https://www.oecd.org/going-digital/ai/principles/

89 https://www.microsoft.com/en-us/research/theme/fate/

90 https://www.blog.google/technology/ai/ai-principles/

91 https://www.partnershiponai.org/partners/

92 https://www.niti.gov.in/sites/default/files/2021-02/Responsible-AI-22022021.pdf

in February 2021. Also, NITI Aayog highlighted approaches of operationalising principles of AI through documents "*Approach Document for India: Part 2 - Operationalizing Principles for Responsible AI*"[93] published in August 2021. NITI Aayog approach paper suggested a need for custodians to manage and implement these principles in AI systems. The custodian may guide sectoral regulators on the same. NITI Aayog also proposed a risk-based approach for adoption of AI applications. Under this approach, adoption of these principles may vary based on the risk associated with each AI applications. NITI Aayog classified risks into following categories and the actions for each category:

a. **High Risk (likely to cause harm or has a negative impact):** Consider increased scrutiny and mandate responsible AI practises.

b. **Low risk:** Effort to minimise the regulatory burden. Self-regulation and awareness campaigns. Supporting structures to enable accountability, transparency and grievance redressal may be required for self-regulation to be effective.

c. **Areas where the risks are not clear:** Regulatory mechanisms may be developed through policy sandboxes and controlled deployments where market reactions and impact could be closely monitored.

3.5.2.　From a sectoral perspective such as telecom sector, some of the issues might be different and may require to apply principles of Responsible AI in the context of telecom scenario. NITI Aayog in its approach paper has mentioned that extant regulation will continue to oversee AI-led innovations in domains under their purview for the time being. The approach to handle sector-agnostic risks or challenges associated with AI in the sector will require alignment with the policies and initiatives

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[93] https://www.niti.gov.in/sites/default/files/2021-08/Part2-Responsible-AI-12082021.pdf

framed by sectoral ministries and agencies involved in taking decisions with regard to AI.

3.5.3.   For this purpose, an authority or a body or an institution may be required to be established which can frame requisite guidelines, take necessary initiatives and oversee the compliance. This authority or a body or an institution may also facilitate sharing of future telecom network capabilities and its role in achieving national objectives for the development and deployment of AI based solutions in other sectors. Also, there will be a need to examine the legal framework under which such authority or a body or an institution can be constituted. Evidently, on the basis of best practices in different jurisdictions as discussed in previous chapter it seems there will be need of a new law to handle AI and related technologies.

3.5.4.   The body or institution or group so established, may have a mechanism of consulting the relevant stakeholders such as telecom service providers, researchers, consumer groups, associations, organisations, sector regulator, ministries and department concerned

3.5.5.   **Risk management as a design principle**

i.   In this fast-changing world, traditional methods for risk management are ineffective. Waiting until after the development of AI models to determine where and how to mitigate risks is too inefficient and time consuming in a world of rapid AI deployments. Managing risk cannot be an after-thought or addressed only by model-validation functions. Instead, risk analysis should be part of the initial AI model design, including the data collection and governance processes. Perhaps, oversight should be concurrent with AI development.

ii.   As there is no cure-all for the broad spectrum of AI risks, organizations must apply an informed risk-prioritization plan as the initial step in an effective, dynamically updated AI risk-management approach anchored in both legal guidance and technical best practices. In this regard, learning from past experience i.e. the review of past risk

failures is helpful in AI risk mitigation because AI draws its predictive power from past events, deriving insights from databases of previous incidents helps in creating a strong risk mitigating system.

Issues for consultation

Q.8. Whether risks and concerns such as privacy, security, bias, unethical use of AI etc. are restricting or likely to restrict the adoption of AI? List out all such risks and concerns associated with the adoption of AI. Please justify your response with rationale and suitable examples, if any.

Q.9. What measures are suggested to be taken to address the risks and concerns listed in response to Q.8? Which are the areas where regulatory interventions may help to address these risks and concerns? Please justify your response with rationale and suitable examples, if any.

Q.10. What measures do you suggest to instil trust and confidence regarding a robust and safe AI system among customers, TSPs and other related entities/stakeholders? Whether adopting general principles such as Responsible AI and ethical principles at the time of designing and operationalising the AI models will help in developing ethical solutions and instilling trust and confidence in the users? What may be such principles and who should formulate these and how compliance can be ensured? Please justify your response with rationale and suitable examples, if any.

Q.11. Whether there is a need of telecom/ICT sector specific or a common authority or a body or an institution to check and ensure compliance of national level and sector specific requirements for AI? If yes, what should be the composition, roles and responsibilities of such authority or body or institution? Please justify your response with rationale and

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suitable examples or best practices, if any.

Q.12. **In response to Q.11, if yes, under which present legal framework or law such authority or body or institution can be constituted and what kind of amendments will be required in the said law? Or whether a new law to handle AI and related technologies is a better option? Please justify your response with rationale and suitable examples or best practices, if any.**

CHAPTER 4

KEY CONSTRAINTS IN ADOPTION OF ARTIFICIAL INTELLIGENCE AND BIG DATA

4.1. Introduction

4.1.1. The previous chapter highlights opportunities and risks or challenges associated with adoption of AI and BD in the telecom sector. Globally, including India, various initiatives have been taken to mitigate these risks and challenges to leverage AI. Besides the risks hindering the adoption of AI and BD, there are constraints which further restrict organisations or sectors to utilise full potential of AI technologies. Few of these constraints, as projected by various organisations and stakeholders are mentioned below:

i. Ericsson[94] in November 2020 conducted a study on the implementation challenges of AI and categorised challenges in three major categories. First is technology and its cost of deployment, which includes use of tools for accessing and extracting data. The second is the organisation in terms of its structure, budget provisions and availability of trained manpower. Third is people/culture for adoption of AI, which includes employee expectations and behaviour such as fear of job loss, the unwillingness to change and fear of loss of control.

ii. In addition to above, McKinsey & Company[95] in a report highlighted following constraints, which hinder adoption of AI by organisations:

    a. Functional silos constrain end to end AI solutions

    b. Lack of leaders' ownership of and commitment to AI

    c. Lack of technological infrastructure to support AI

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[94] https://www.ericsson.com/4ab2b3/assets/local/reports-papers/industrylab/doc/adopting-ai-report.pdf

[95] https://www.mckinsey.com/featured-insights/artificial-intelligence/ai-adoption-advances-but-foundational-barriers-remain

> d. Uncertain return on AI investments
>
> e. Lack of clear strategy for AI
>
> f. Limited usefulness of data

iii. Further, in virtual conference held in Aug 2020 at TRAI on the subject, various stakeholders mentioned following key constraints which hinder adoption of AI and BD in the country:

> a. Lack of enabling policies.
>
> b. Less clarity in licence agreement.
>
> c. Lack of formal regulation on data management and its sharing.
>
> d. Difficulty to upgrade existing network.
>
> e. Non-availability of appropriate and adequate skill-sets for AI work.
>
> f. Lack of technological infrastructure to support AI.
>
> g. Lack of standardisation.

4.1.2. **AI and BD in telecom sector:** To adopt AI and BD in telecom sector, following players may play critical role:

i. A telecom operator who may develop its own AI solution for operations and management of the network by using data.

ii. A solution provider who develops AI solutions for operators and others to use.

iii. Further, player like researchers, start-ups, individuals and SMEs may develop and offer AI solutions to telecom sector as a new business opportunity.

However, players mentioned above have common constraints in adoption of AI and BD such as data accessibility, privacy and regulatory obligations. These players have limited or suboptimal solutions due to incomplete or no access of telecom data and a platform for demonstration and experimentation. All these possible challenges and constraints are discussed in the following sections in detail.

4.1.3. The list of constraints mentioned below is non-exhaustive. Further, the key constraints are categorised into sector agnostic and sector specific constraints for solution providers and players such as start-ups, researchers and SMEs.

4.2. Sector Agnostic Constraints

4.2.1. **Access to Data**

   i.   As discussed in Chapter 2, data is the basic requirement for an AI system. However, practically data accessibility is one of the major constraints. The effectiveness and efficiency of AI model depends on data provided for its training and testing. Thus, to improve overall services of the telecom sector, the telcos, solution providers and other key players might need data or insights of the entire telecom network. However, in all these scenarios, data accessibility is a critical constraint.

   ii. Currently, most of the data may be either available with a few big organisations or with the Government agencies. The organisations holding major portion of data may not be interested in sharing the same due to privacy, security concerns of their customers/organisations and also due to strategic business decisions. The customers may be reluctant to share their data due to the concern of privacy. Further, data available in public may have inherent biases, incomplete or in improper format.

   iii. Thus, to gear up adoption of AI, data may need to be made accessible with necessary insights to the concerned agencies. For instance, in Graph Neural Networking Challenge 2021, launched by ITU, participants were required to use the GNN approach where the dataset[96] was provided by the ITU. This data was generated with a simulated network and was not obtained from a real network. If real network data is made readily available to the AI solution developers,

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[96] https://bnn.upc.edu/challenge/gnnet2021/dataset/

efficient solutions could be formed.

iv. Thus, initiatives are required to be taken to make the data accessible.

v. Once data is made available, its handling include activities such as storage, pre-processing, integration, protection, provenance among others. As per ITU Recommendations on Big data[97], each activity in data handling has certain requirements which need to be fulfilled for providing cloud services efficiently. These requirements include data collection process which requires collection of data from multiple sources in parallel. Similarly, data storage processes require support for different data types with sufficient storage space, elastic storage capacity and efficient control methods to support storage for different data formats. Data formats include text, spreadsheet, video, audio, image, and map. Here, each activity in data handling has different requirements and fulfilling these requirements is a challenging task, especially, in case of telecom data, where data is generated in large quantum. Thus, a framework to handle the data for AI modelling may be required to address these issues.

4.2.2. A tussle between privacy and utility of data

i. As discussed above, accessibility to user data may improve the overall performance of AI systems. However, users are concerned about their privacy which may be compromised while sharing data or insights for AI operations. These concerns may include identification, tracking and profiling of the individuals. Therefore, risks of privacy may become a constraint while using the data for AI applications.

ii. Encryption offers one of the ways to protect data from adversaries. Since data can exist in three different states: at rest, in transit, and in use, the standard encryption is used for the data in rest and transit only whereas the data in use is the most vulnerable form. It is also a fact that as the strength of encryption is increased, the data becomes seemingly

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[97] https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Y.3600-201511-I!!PDF-E&type=items

uncorrelated with the plaintext data[98]. The information on website of Statistics Canada[99] also shows the trade-off between privacy and utility of data. However, to work with data i.e., to perform analysis, computation and mathematical operations, one requires the fundamental relationship and correlations which was removed by encrypting the data. Current solutions almost universally decrypt the data to use it, but this exposes unencrypted and sometimes private data, leading to legal and ethical challenges as well as increasing vulnerability to bad actors. The current endeavour is to find a solution to this tussle between data protection and loss of data utility.

4.2.3. **Need for an AI specific infrastructure**

i. AI, more specifically ML requires processing huge numbers of calculations quickly, thus necessitating increased processing power. As per an approach paper on AIRAWAT[100] published by NITI Aayog, developing ML solutions can be seen as a two-step process: (a) training and (b) inference. The training phase is essentially an optimization problem in a multi-dimensional parameter space and involves building a model that can be used to provide a wider generalization in the inference process. Once trained, the model now needs to be deployed on real-world data in the inference mode. For many applications, this inference step needs a trained model that is fixed for consistency, reproducibility, liability, performance or regulatory reasons. The demands and intensity of training and inference would thus determine the need for advanced processing capabilities.

ii. For successful adoption of AI in the telecom sector, AI must be able to handle large data sets, both real-time and post-processed data. Thus, to compute large data for AI applications, there is a requirement of high computing technologies such as GPUs, TPUs to handle these large datasets. Further, as per NITI Aayog report[101], AI adoption in India will

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[98] https://www.csis.org/analysis/data-protection-or-data-utility
[99] https://www.statcan.gc.ca/en/data-science/network/privacy-preserving
[100] https://www.niti.gov.in/sites/default/files/2020-01/AIRAWAT_Approach_Paper.pdf
[101] https://indiaai.gov.in/documents/pdf/NationalStrategy-for-AI-Discussion-Paper.pdf

face the challenges due to high cost and low availability of computing infrastructure that is required for model development, training and integrating with AI based services.

4.2.4. Lack of Standardisation – Interoperability and Compatibility

i. Like several other pioneering areas of science and technology, the development of AI raises a host of legal, ethical, and societal issues that create real and perceived challenges for developers, policy makers, and users including the general public. These aspects should be considered in the policy realm to be applied in the development and deployment of AI technologies and systems. Standards are the tools for implementing or informing policies and principles related to such issues. The need for standards for AI is highlighted by the following departments/agencies working on AI:

a. The Task Force on "AI for India's Economic Transformation" constituted by the Ministry of Commerce and Industry in Aug 2017, in its report published in March 2018, recommended to work on data storage and privacy standards, standards for autonomous systems, standards for interoperability between AI based systems, standards for design, development and deployment of AI systems, and participation in AI based international standards setting discussions.

b. The Committee on "Platforms and Data for AI" constituted by MeitY in 2018, recommended to develop a generalised meta-data standard to enable integration of variety of resources including data, tools and literature from multiple resources and owners of these resources.

c. The Department of Telecommunications (DoT)[102] had also formed an AI standardisation committee to develop various interface standards and India's AI stack. The stack so developed will be structured across all sectors ensuring protection of data, data federation, data minimisation, open algorithm framework, defined data structures, interfaces and

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[102] https://www.tec.gov.in/pdf/Whatsnew/ARTIFICIAL%20INTELLIGENCE%20-%20INDIAN%20STACK.pdf

protocols, proper monitoring, audit and logging, data privacy, ethical standards, digital rights and trustworthiness.

ii. The above discussion emphasises on developing standards for data handling (collection, storage, and integrations etc), data sharing, protection of data, privacy and ethical standards for adoption AI. The need for standards for AI is considered by various countries. Following countries have started working towards developing standards related to AI:

a. **United States of America:** On February 11, 2019, the President issued an Executive Order (EO)[103] directing federal agencies to ensure that the nation maintains its leadership position in AI. Among its objectives, the EO aims to "*Ensure that technical standards reflect federal priorities for innovation, public trust, and public confidence in systems that use AI technologies and develop international standards to promote and protect those priorities.*" The EO directs the Secretary of Commerce, through the National Institute of Standards and Technology (NIST), to issue "a plan for Federal engagement in the development of technical standards and related tools in support of reliable, robust, and trustworthy systems that use AI technologies." Accordingly, NIST prepared the plan[104] and published it on August 9, 2019.

b. **European Union:** On 21st April 2021, the proposal[105] for regulation laying down harmonised rules on AI (Artificial Intelligence Act) and amending certain union legislative acts was published. Under this, the establishment of the **European Artificial Intelligence Board** was proposed to facilitate their implementation, as well as drive the development of standards for AI.

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[103]
https://www.nist.gov/system/files/documents/2019/08/10/ai_standards_fedengagement_plan_9aug2019.pdf
[104]
https://www.nist.gov/system/files/documents/2019/08/10/ai_standards_fedengagement_plan_9aug2019.pdf
[105] https://eur-lex.europa.eu/resource.html?uri=cellar:e0649735-a372-11eb-9585-01aa75ed71a1.0001.02/DOC_1&format=PDF

c. **Germany:** With respect to standardisation, the German Federal Government proposed the following initiatives[106],

- The German standardisation roadmap on AI describes the environment in which AI standardisation operates. The roadmap also identifies existing standards, and specifications relevant to the field of AI, and outlines further standardisation needs. Even though it was published at national level, it focuses primarily on European and international standardisation efforts.

- Funding for the development of data standards and formats to encourage EU-wide collaborations.

- Funding for experts, particularly from SMEs and start-ups in order to support their participation in international standardisation processes.

d. Similarly, countries such as Norway[107], Australia[108], United Arab Emirates[109], China[110], Canada and Singapore[111] are also working on standardisation of AI.

4.2.5. **Lack of Research and Development**

i. As discussed, AI has huge potential to revolutionise how we live, work, learn, discover, and communicate. However, AI finds limited applications due to constraints related to data, model, privacy, computing infrastructure etc. These constraints may be addressed by active research with the aim of finding solutions. Let us understand where research is needed with the following examples:

a. Telecom networks generate a large volume of data. However, the data available may be of bad quality for training AI models. This bad quality of data may affect the AI modelling and finally the applications. Bad

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[106] https://knowledge4policy.ec.europa.eu/ai-watch/germany-ai-strategy-report_en
[107] https://knowledge4policy.ec.europa.eu/ai-watch/norway-ai-strategy-report_en#aireport
[108] https://www.standards.org.au/getmedia/ede81912-55a2-4d8e-849f-9844993c3b9d/1515-An-Artificial-Intelligence-Standards-Roadmap12-02-2020.pdf.aspx
[109] https://sdaia.gov.sa/ndmo/?Lang=en&page=SectionPolicies#
[110] https://www.airuniversity.af.edu/Portals/10/CASI/documents/Translations/2021-03-02%20China%27s%20New%20Generation%20Artificial%20Intelligence%20Development%20Plan-%202017.pdf?ver=N2TtRVNODYyWR0yGHuK_cA%3d%3d
[111] https://stip.oecd.org/stip/policy-initiatives/2019%2Fdata%2FpolicyInitiatives%2F24364

quality of data may arise due to various reasons such as improper format, redundancy, biases and incompleteness of data and many more. Thus, there may be a need to move towards innovative ideas or approaches to address these problems.

b. Data is important for AI applications, and the variety of enriched data will aid applications of AI. However, privacy is one of the concerns. To make data more secure, various encryption and anonymisation techniques may be adopted by the experts. However, this may limit the data usage for the AI modelling. Therefore, it is a difficult task to ensure efficient utilisation of data in AI modelling and ensure security of the data at the same time. Thus, further research may be required to address such concerns.

c. To build trust and confidence in AI based applications, there is a need to address concerns like biasedness, lack of explainability, risk of non-compliance of regulatory requirements and loss of direct control.

ii. Further, areas which require active research to develop innovative solutions in the field of AI include economic activities, education quality of life and national security. However, various organisations, departments and agencies working in the field of AI mentioned that there are various concerns in the field of research which need to be addressed to boost the research and development.

iii. In India, NITI Aayog highlighted concerns related to research and development on AI in its National Strategy on Artificial Intelligence. These concerns are listed below:

a. Majority of the talent pool is focused on routine IT development and not so much on research and innovation.

b. A majority of the small population focused on research prefers to pursue advanced degrees to subsequently apply their expertise abroad.

c. Indian IT services companies, like TCS, Wipro and Infosys, have been the flag bearers of India's competence in implementation of cutting-edge

technology solutions, yet their contribution to research has been limited.

The research ecosystem still has several obvious gaps. The detailed project report of Inter-Ministerial National Mission on Interdisciplinary Cyber Physical Systems has highlighted some of the concerns as:

a. Lack of collaborative/ interdisciplinary approach: Research is mostly focused in silos in academic institutions.

b. Lack of scale for experimental validation: Due to various practical and financial reasons, research is largely restricted to theoretical or laboratory scale.

c. Lack of facilities to support large scale experimental test beds

d. Lack of connection with stakeholders like entrepreneurs and industry to convert research outputs to commercial products.

iv. As discussed above, research in the field of AI plays a key role in supporting the mission to leverage these technologies. However, it is necessary to address various challenges and issues associated with research and development in AI.

4.2.6. **Finding the right talent**

Technical skills and data literacy are obviously important for AI and BD. Most enterprises have an abundance of data but leveraging it for AI projects require skills. This includes data transformation to develop and deploy automated data pipelines that deliver high-quality data along with the knowledge of ML concepts and analytics tools to perform analysis. As per a 2019 survey report by Gartner[112] lack of skill is one such challenge in AI adoption. 56% of respondents said that acquiring new skills will be required for adoption of AI. On similar lines, International Data Corporation (IDC)[113] reports about 74% of the enterprises stated that lack of skill impedes overall innovation. As such, importance of skill and

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[112] https://www.gartner.com/smarterwithgartner/3-barriers-to-ai-adoption/
[113] https://www.idc.com/getdoc.jsp?containerId=prAP48071721

expertise is imperative before adopting AI solutions or this would create trust and reliability issues.

4.3. Sector Specific Constraints

4.3.1. Functional Silos in Telecom Sector

The term functional silos refer to the paradigm of working in silos with no or minimal collaborations. A survey conducted by McKinsey & Company[114], highlights that 30% of respondents of organisations who have piloted or embedded AI, stated that functional silos is one of the constraints that hinders the growth and maturity of AI solutions in the market. In telecom sector too, telcos might be working towards improving their own services and products. They may be less interested in working in a collaborative manner to improve the overall performance of the telecom sector. However, the risks and constraints associated with AI and BD require a collaborative approach to address them. The collaborative approach not only addresses the constraints, but it may also be beneficial for developing innovative solutions and products for improving the performance of the overall telecom sector.

4.3.2. Lack of platform for experimentation and demonstration

Currently, AI solutions and products may be limited in the market. The telecom operator may deploy AI solutions either by developing AI solutions on premises or by adopting solutions developed by solution providers. The operator developing its own AI solutions may be having a platform for testing their products and solutions on a real time network. However, the players such as solution providers, start-ups, researchers and individuals interested in developing AI solutions and products may not get opportunities to test and deploy their solutions on real networks. The other interested players might not get enough opportunities to demonstrate their solutions. This may restrict innovative solutions or approaches to deal with the constraints and risks associated with AI and to accelerate the adoption

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[114] https://www.mckinsey.com/featured-insights/artificial-intelligence/ai-adoption-advances-but-foundational-barriers-remain

of AI. Thus, to develop optimal solutions and to deal with the risks and constraints of AI, all the players in the telecom sector should get enough opportunities to demonstrate and test the AI solutions.

4.3.3. **Initial investment overhead**

i. Considering soaring data generations and inefficiency of traditional tools and methods to process them effectively, it is essential to adopt AI. The adoption of AI requires initial investments to build the necessary system which includes costs on:

    a. Collecting, digitalising and organising data from internal and external sources

    b. Computation power for training and testing models

    c. Skills and expertise to design, develop, train, and deploy AI systems

Above points, though non-exhaustive contribute towards investment overheads and may hinder adoption of AI.

However, economies of scale apply to AI as well. An AI model or system once trained can be utilised in different applications, at a relatively lower cost. Making an initial investment does not mean that one has to continue making the same investment at each step. Here, it may be noted that, since impact of AI is likely to build up at an accelerated pace over a time, and therefore the benefits of initial investment may not be visible in the short term.

4.3.4. **Regulatory Impediments**

i. Regulatory requirement is an affirmative duty on an organisation to complete and refrain from a set of actions so as to remain compliant with the law. With the advancement in technology and market requirements, sometimes granularity in regulations impedes growth and hinders adoption of emerging technologies. These can be mitigated by understanding the challenges and making necessary regulatory changes or if required, framing new policies.

ii.   TSPs are regulated by a number of laws, including the Indian Telegraph Act, 1885 (Telegraph Act), TRAI Act, 1997, the terms of the licence agreement entered into between the TSP and the Government, and rules and regulations framed by the Government and TRAI from time to time. This section outlines some of the reasons which may hinder adoption of technologies like AI and big data in telecom sector are:

   a. **Bringing more clarity in licence agreement:** For instance, in the course of delivering their services, telecom service providers have the ability to gain access to a lot of information and data pertaining to their subscribers. This includes Call Detail Records (CDR), calling patterns, location data, data usage information, etc. Though above-mentioned data is personal data of an individual, the ownership rights, authority to use, transfer and delete this data are presently ambiguous. There could be other aspects where clarity is required.

   b. **Lack of formal regulation for data:** One important aspect of AI systems is data itself. The issue arises due to lack of formal regulation around data handling. It includes the collection, processing, sharing, deleting, etc. On 11 December 2019, the Ministry of Electronics and Information Technology (MeitY) introduced the draft Personal Data Protection Bill, 2019 (PDP Bill) before the Parliament, which was referred to a Joint Parliamentary Committee (JPC) for further consideration. After carrying out a series of consultations with stakeholders, the JPC published its report along with the finalised Data Protection Bill 2021 (DP Bill) on 16 December 2021. In August 2022, The PDP Bill 2019[115] was withdrawn after parliamentary committee recommended changes, the Government is now working on a new comprehensive legal framework for the digital ecosystem.

   c. **Obsolete KPIs:** Improvement of performance of the network might pose risks of non-compliance from the regulator perspective as the system might fail to show improvement in KPIs defined by the

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[115] https://prsindia.org/billtrack/the-personal-data-protection-bill-2019#:~:text=The%20Personal%20Data%20Protection%20Bill%2C%202019%20was%20introduced%20in%20Lok,Protection%20Authority%20for%20the%20same.

regulator. The issue may be due to static and obsolete KPIs which require reform with new developments, else it may hamper growth in the sector.

iii.   The role of policy maker is to identify hindrances faced by industry and address the same in an effective manner. Regulatory intervention is required in three scenarios. First, where industry is unable to realise or unleash full potential of AI and BD in the instant case. Second, when direct/indirect harm is inflicted on others. Lastly, when collaboration of stakeholders is required for creating a comprehensive ecosystem for implementation of solutions offered.

Issues for consultation

Q.13.   Whether telecom/ICT industry is facing constraints such as access to data, lack of computing infrastructure, lack of standards, and R&D in the adoption of AI and BD technologies? Please list out all such constraints with adequate details.

Q.14.   What measures are required to make data and computing infrastructure available and accessible to developers and also to make data/AI models interoperable and compatible? Please respond along with examples, best practices and explanatory notes.

Q.15.   Whether there is a gap between requirement and availability of skilled AI workforce? If so, what measures are required to be taken to ensure availability of adequate skilled workforce in AI domain? Please respond along with suggestions with supporting details and best practices.

CHAPTER 5

ENABLERS FOR ADOPTION OF ARTIFICIAL INTELLIGENCE AND BIG DATA FOR CROSS SECTOR UTILIZATION

5.1. As discussed in previous chapters, AI and BD hold vast opportunities for the telecom and other sectors. At the same time, there are certain risks and constraints which need to be addressed for accelerating the adoption of AI and BD technologies in various sectors.

5.2. This chapter details about enablers for adoption of AI and BD. These enablers not only address the key constraints but also accelerate adoption of AI. The subsequent discussion details few key enablers for making available and accessible requisite data, computational infrastructure and AI workforce along with other important activities required for the development, training, validation and adoption of AI models.

5.3. Data Democratisation

5.3.1. As discussed in chapter 2, data is essential for adoption of AI as data is the basis for training and validation of AI models. Thus, industry should work extensively to harness data generated from every node of network to support future AI innovations. However, chapter 4 highlights that there is a lack of access to dataset. Various attempts have been made globally to make the data accessible through various initiatives and strategies at national level. Some of these initiatives are listed below:

i. **USA[116]:** High quality datasets are critically important for training many types of AI systems. The National AI Initiative directs Federal agencies to provide and facilitate the availability of curated, standardised, secure, representative, aggregate, and privacy-protected data sets for AI research and development. One

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[116] https://www.ai.gov/strategic-pillars/infrastructure/#Data-Resources-for-AI-RD

of the recommendations by the Working Group on AI (AIWG), formed by FCC, suggests that FCC could begin to explore the feasibility of promoting the development of a data exchange to promote the sharing of privately held data.

ii. **United Kingdom[117]:** In the UK, policy initiatives focus on development of a trustworthy and qualitative data infrastructure. This includes exploring and defining a framework for safe, secure and equitable data transfer, developing a data infrastructure to make available high-quality public data in an open, reusable and accessible format for machine learning.

iii. **Germany**[118]**:** Germany took policy initiative to create a comprehensive mobility data. The aim is to make available mobility data (real and synthetic training and test data) that can be used across competitors for the research, development, validation and certification of reliable AI algorithms in order to promote the development of autonomous driving in Germany. As per information published on website[119] of The Federal Ministry for Digital and Transport, in spring 2022, offered a new central, standardised and user-friendly way to access the mobility data via mobility library known as the Mobilithek. This platform will be the national access point for mobility data and implementation requirements from delegated regulations on the European ITS Directive and the amended Carriage of Passengers Act. This is a platform for mobility providers, infrastructure managers, transport authorities and information providers to share digital information.

iv. **Singapore:** In June 2019, IMDA released the Trusted Data Sharing Framework[120] to help companies overcome challenges in addressing trust between data providers and develop "trusted

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[117] https://knowledge4policy.ec.europa.eu/ai-watch/united-kingdom-ai-strategy-report_en
[118] https://knowledge4policy.ec.europa.eu/ai-watch/germany-ai-strategy-report_en#aireport
[119] https://www.bmvi.de/SharedDocs/EN/Articles/DG/mobilithek.html
[120] https://www.imda.gov.sg/programme-listing/data-collaborative-programme

data". To spur the growth and innovation of AI-related apps in the nation, IMDA also set up free and open-source AI libraries. These libraries contain collections of APIs, source codes, databases and more.

v. **Netherlands**: The Netherlands AI Coalition[121] (NLAIC) put forward a proposition of responsible data sharing in AI across organisational boundaries to develop a positive climate and creating a governance model to facilitate data sharing.

5.3.2. Similarly, in India, various government departments and agencies have observed the need to make data available for AI models. Following are the key initiatives taken and recommendations proposed to make data accessible for developing AI solutions in India:

i. The Task Force on Artificial Intelligence, constituted by the Ministry of Commerce, recommended setting up digital data banks to ensure availability of cross-industry data and creation of interdisciplinary large data centres in its report[122] published in 2018.

ii. A committee on "Platforms and Data on Artificial Intelligence", was constituted[123] by MeitY in 2018. In 2019[124], the committee recommended to develop an Open National Artificial Intelligence Resource Platform (NAIRP) which will act as a central hub for knowledge integration and dissemination in AI. It proposes to bring data available with governments onto common platforms in well-defined formats, create anonymised infrastructure in order to make large sets of data available to the public for development and call for investment by government in the development of bias-free dataset.

iii. National Strategy on Artificial Intelligence (NSAI) released by NITI

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[121] https://nlaic.com/wp-content/uploads/2020/10/Responsible-data-sharing-in-AI.pdf

[122] https://dpiit.gov.in/sites/default/files/Report_of_Task_Force_on_ArtificialIntelligence_20March2018_2.pdf

[123] https://www.meity.gov.in/artificial-intelligence-committees-reports

[124] https://www.meity.gov.in/writereaddata/files/Committes_A-Report_on_Platforms.pdf

Aayog in 2018 highlighted the necessity for the government to explore assistance in building a large corpus of data across domains. Enabling access to high quality and representative datasets for evaluating AI models on ethical principles is also not available many times. This issue was raised in a recent publication by NITI Aayog[125].

5.3.3.   It is obvious from above that multiple initiatives have either been taken or being proposed at national level to make the data accessible for training and validating AI models. These initiatives are generic in nature and applicable for every sector. However, to accelerate adoption of AI in the telecom and broadcasting sector, specific requirements are to be set up by creating data hubs with necessary infrastructures for developing, training and validating AI models. The AI models developed for telecom sector may be used for other sectors also by accessing requisite execution environment to run the AI models.

5.3.4.   In addition to setting up data hubs, it is required that people, industry, big corporate and the government share the data available with them. There is also a requirement to establish an authority or a body or an institution whose role should also be to act as manager and gatekeeper for data stored. Its role should also cover to manage the privacy and security of data. Further, authority or body or institution so established may collaborate with various sectors and Government agencies to make the data available for AI. The authority or body or institution may also prepare framework to share the data between different agencies. It may also take initiatives to encourage people, industries, the Government agencies etc. to share data for AI modelling.

5.3.5.   **Synthetic Data for Securing Privacy:** Further, in addressing the concerns of privacy, instead of sharing real data synthetic data

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[125] Approach Document for India Part 2 – Operationalizing Principles for Responsible AI

approach may be helpful. Gartner[126] mentions that synthetic data is a class of data that is artificially generated. As real data is always the best source of insights from data, but access to real data is often expensive, imbalanced, unavailable or unusable due to its character of generation and privacy issues. Synthetic data can be an effective supplement or alternative to real data, providing access to better annotated data to build accurate, extensible AI models. When combined with real data, synthetic data creates an enhanced dataset that often can mitigate the weaknesses of the real data. It can be used to train, test, validate new AI system where live data doesn't exist or it is biased. It can also be used to supplement small, existing datasets which was currently being ignored. Further, the organisations can alternatively choose synthetic data when real data can't be used can't be shared or can't be moved. Gartner predicted that by 2030, synthetic data will completely overshadow real data in AI models. In this sense, development of synthetic data can be a game changer approach. Also, the latest development in AI, Generative Adversarial Network (GAN), is being extensively used to reduce the need for real data. A white paper[127] by University of Oulu proposed to address the inconsistencies in heterogeneous sensory data, edge intelligence can resort to generalized adversarial networks (GAN), in which synthetic data can recover and restore the data consistency.   A synthetic dataset may prove to be more lucrative than real data for AI modelling. The authority or body or institution proposed in subsection 5.3.4 can undertake creation, management and other important aspects of synthetic dataset.

Issues for consultation

Q.16.   What initiatives do you suggest to democratise data

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126   https://www.gartner.com/en/newsroom/press-releases/2022-06-22-is-synthetic-data-the-future-of-ai#:~:text=Synthetic%20data%20is%20often%20treated,real%20data%20in%20AI%20models.
127   http://jultika.oulu.fi/files/isbn9789526226774.pdf

required to develop AI models in the telecom sector? Please justify your response with rationale and suitable examples, if any.

Q.17. **Whether the authority or body or institution as suggested in response to Q.11 may also be entrusted with the task to manage and oversee collection, cataloguing and storage of data? Whether such authority or body or institution need to be entrusted to generate and make available synthetic data? Please justify your response with rationale and suitable examples, if any.**

Q.18. **Whether the legal framework as envisaged in para 3.5.3 and Q.12 should also enable and provide for digitalisation, sharing and monetisation for effective use of the data in AI without affecting privacy and security of the data? Please justify your response with rationale and suitable examples, if any.**

5.4. Protecting privacy in an AI-driven world

5.4.1. The approach of data democratisation discussed above poses risk of privacy to customers of the telecom operators. The concern of privacy becomes an unequivocal issue for the telcos and government agencies.

5.4.2. One of the ways to ensure privacy of the data is offered by encryption techniques and algorithms as mentioned in para 4.2.2. However, adoption of these techniques increases processing overheads, delay in output and above all loss of data utility.

5.4.3. Further, the approach of adoption of legal frameworks such as laws or regulations, may be an option to protect the privacy of data which may allow players to use data through a defined process and after taking consent of the users prior to using data for such models. However, it is important to understand that rules and regulations to stifle access and use of data may hinder adoption of AI. And on the other hand, relaxed rules and regulations on use of personal data may compromise privacy. These are two extreme sides of the spectrum. It

is difficult to find a balanced approach to address this concern through rules or laws. Therefore, a solution has to be worked out by using suitable technology.

5.4.4. To overcome the limitations of data encryption, there are techniques which allow data to remain encrypted while in use and can still be operated upon without jeopardizing privacy. These new techniques are known as "privacy preserving technologies[128]" or "privacy enhancing technologies[129]". These technologies include data anonymization, differential privacy, secure multi-party computation, homomorphic encryption among others. These are discussed in detail below:

i. **Data anonymization** hides or removes sensitive attributes such as personally identifiable information (PII), so that the subject cannot be identified within the modified dataset. However, hiding or removing the personally identifiable information may reduce the utility of the dataset.

ii. **Differential Privacy** is another advanced solution of privacy preserving technique in which random noise is added to the true outputs using rigorous mathematical measures. However, the original aggregate dataset and differentially additive noise one are statistically indistinguishable. Thus, a single individual cannot be identified if a statistical query is raised. However, there is a trade-off between privacy guarantee and utility because adding too much noise and improper randomness may significantly depreciate the reliability and usability of the dataset.

iii. **Secure Multi-Party Computation** is another privacy preserving technique where any computation can be performed on the overall dataset (owned by individual party) without revealing the individual dataset. For example, a group may want to calculate

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[128] https://www.statcan.gc.ca/en/data-science/network/privacy-preserving
[129] https://unstats.un.org/bigdata/task-teams/privacy/UN%20Handbook%20for%20Privacy-Preserving%20Techniques.pdf

the average salary of all employees but without revealing their individual salaries. Here multi-party computation may be used.

iv. **Homomorphic Encryption** enables the ability to perform computation on the encrypted form of data without the need for the secret keys to decrypt the ciphertext. The results of the computation are in encrypted form and can only be decrypted by the requester of the computation. In addition, homomorphic encryption ensures that the decrypted output is the same as the one computed on the original unencrypted dataset.

5.4.5.   A whitepaper by University of Oulu[130] highlights that utilizing the technologies of differential privacy, homomorphic encryption, and secure multi-party computation in designing privacy-serving AI model parameter-sharing schemes, can further enhance privacy.

5.4.6.   These technologies will, in time, may redefine the way data is used for the benefits of consumers, enterprises and governments in the telecom sector and beyond. For example, these technologies can reshape how operators and technology providers cooperate over the data, but also how future technologies such as Cloud Services, 5G technologies and the Internet of Things will enable benefits of Fourth Industrial Revolution (Industry 4.0) while limiting the potential harm to the society including the loss of individual privacy.

5.4.7.   Nokia in its whitepaper titled "Nokia evaluates privacy-preserving technologies to protect personal data and enable new telco use cases[131]" highlighted use cases such as data innovation, data collaboration, data delegation, data monetization etc. which are supported by privacy preserving technologies. Further, it mentions new use cases and applications enabled by privacy preserving technologies. These use cases are mentioned in table 5.1 given below:

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[130] http://jultika.oulu.fi/files/isbn9789526226774.pdf
[131] https://d1p0gxnqcu0lvz.cloudfront.net/documents/Nokia_leverages_privacy-preserving_technologies_to_protect_personal_data_White_Uv2gD5z.pdf

Table 5.1: Privacy Preserving Technologies and their Use Cases

Use cases & applications	Data Synthesisation	Homomorphic Encryption	Differential Privacy	Federated Learning	Secure Multiparty Computation
Data Retention	*		*		
Secure Data Mining	*	*	*		
Internal Data Sharing	*	*	*		
Cloud Migration	*	*	*	*	
Data Monetization	*	*	*	*	*
Product Development	*		*		
Vendor validation	*		*		
AI/ML Model Training	*	*	*	*	*
Edge Computing				*	

5.4.8. However, there are apprehensions that powerful tools and techniques are available which can de-anonymise and reveal the dataset that way breaching the privacy of the data. A person attempting to de-anonymize makes use of additional information available from various sources. An article[132] from The Guardian quotes that researcher from Belgium's Université catholique de Louvain (UCLouvain) and Imperial College London have built a model to estimate how easy it would be to de-anonymise any arbitrary dataset. If apprehensions are not allayed, then sharing of data using the data science techniques may not be of any help for all practical purposes as users would be reluctant to share. There are privacy preserving architectures where such architectures may enable AI models to continually learn from data without requirement to share the data and thereby allaying the fear of de-anonymisation at any stage. Some of these types of architectures

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[132] https://www.theguardian.com/technology/2019/jul/23/anonymised-data-never-be-anonymous-enough-study-finds

have been discussed in subsequent paras.

<div style="border: 1px solid black; padding: 10px;">

Issues for consultation

Q.19. **(a) Which are the currently used privacy enhancing and privacy preserving technologies facilitating adoption of AI and BD? Are there any challenges in using these technologies? How these challenges can be addressed?**

(b) Which are the potential technologies likely to be available in near future to further strengthen privacy?

Please justify your response with rationale and suitable examples, if any.

Q.20. **Whether the list of technologies provided in response to Q.19 are adequate to handle all the perceived risks and concerns in the AI domain? Or is there a need to develop new privacy preserving architecture? Please justify your response with rationale and suitable examples, if any.**

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5.5. Moving AI at Edge

5.5.1. **Pre-requisites should not lead to take away intelligence:** Strength of anonymization or aggregation to protect privacy will depend on tools, techniques, and practises used to carry it out. However, it is to be kept in mind that the strength of privacy preserving technologies may not only protect the privacy but also restrict the AI system to utilise full potential of data. In the process of strengthening privacy, there are chances that part of intelligence might be lost and may be irrecoverable. In turn, full value from the data may not be extracted. Therefore, there is a need to create an architecture which offers strong privacy without losing value and also offers possibility to learn without the sharing of data.

5.5.2. **Importance of insights rather than data:** In fact, intention of the

sector may be more in gaining insights rather than acquiring raw data. If there is a learning mechanism which enables AI to learn without gathering data at the central level, then it may serve both purposes, privacy as well as intelligence. AI at edge may be one of the ways to achieve this. The capabilities of the telecom sector include innovative technologies such as Cloud Computing, Edge Computing etc. that may handle the constraints of privacy. Edge computing sets up a new age computing paradigm that moves AI to where the data generation and computation actually take place. Edge AI allows faster computing and insights, better data security, and efficient control over continuous operation. As a result, it can enhance performance of AI-enabled applications and keep operating costs down. Edge Computing in combination with FL may resolve the issue of data privacy and security and building trust among users. The white paper[133] by University of Oulu proposed that federated learning may be a feasible paradigm for privacy-friendly distributed data training, such that the original datasets are kept in their generated devices/nodes, and the edge AI model parameters are shared. FL has emerged as a prospective solution that facilitates distributed collaborative learning without disclosing the training data. Generally, FL is a technique to implement an AI model in decentralised collaborative learning settings. FL algorithm is executed on multiple local datasets stored at isolated data sources such as smartphones, tablets, PCs and wearable devices. This does away with the need of collecting and processing the training data at a centralised data server.

In Figure 5.1, the steps involved to train a model using the FL framework are shown as detailed below:

- Step 1: Central server sends the latest model parameters to the nodes; Step 2: Data is collected at each node;
- Step 3: Each local model is trained based on the latest parameters; Step 4: Updated model parameters are

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[133] http://jultika.oulu.fi/files/isbn9789526226774.pdf

communicated back to the global model;

- Step 5: Combine update from each model and retrain the global model which is a new model;
- Step 6: Restart from step 1.

**Figure 5.1: Flowchart of Federated Learning[134]**
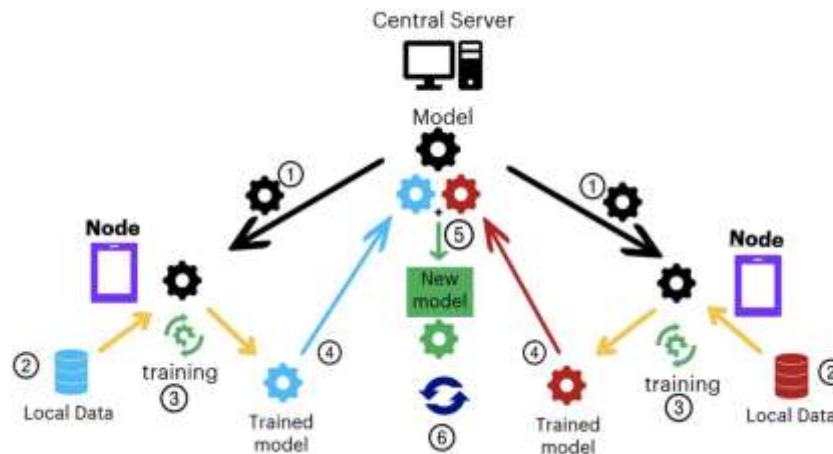
The FL allows local nodes to collaboratively train a shared AI model while retaining both training dataset and computation at internal sites. Only results of the training are exchanged at a certain frequency, which requires a central server to coordinate the training process or utilise a decentralised network to aggregate the training results and calculate the global model. By bringing "the computation to the data" instead of transferring "the data to the computation," FL makes it possible to overcome those challenges by training a centralised model on decentralised data. The figure 5.2 shows how learning and decision making will work on distributed networks.

5.5.3. Federated Learning (FL) is a remarkable approach to handle privacy issues because data is not transferred or shared to the central server, rather model updates are shared with the central server. In telecom networks, implementing a FL architecture may help in adoption of AI techniques where learning happens on entire telecom data rather in

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134 https://medium.com/accenture-the-dock/instilling-responsible-and-reliable-ai-development-with-federated-learning-d23c366c5efd

functional silos. This is important because operators would have the overall perspective and not just their own. Further, the adoption of AI at Edge may be supported by Data Operations (DataOps) and Machine Learning Operations (MLOps) (for details refer para 5.9).

Figure 5.2:   Local and Global Learning and Decision Making in Distributed Networks[135]
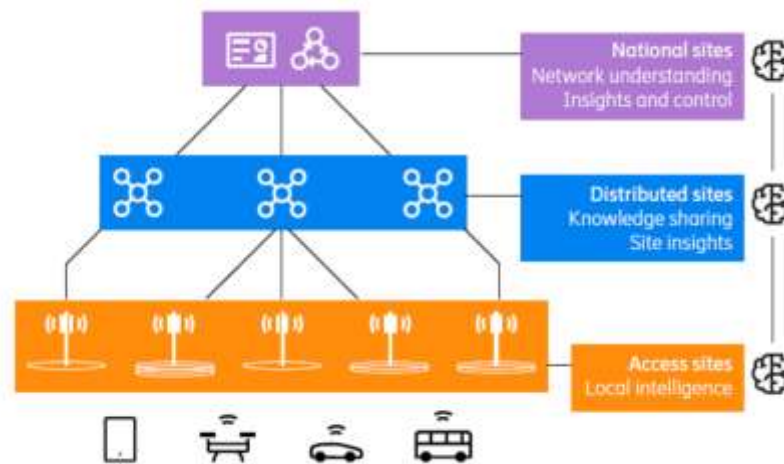
5.5.4. **Laying the foundation for future technologies:** With the adoption of next generation mobile technologies, the telecom network may serve industries and societies by acting as a central communication platform. It would support a wide range of services and will bring digital and physical worlds closer than ever. However, operating large numbers of digital services with different requirements will demand a high degree of autonomy in the operational processes. Thus, industries are proposing an approach of intent driven cognitive radio[136]. Figure 5.3 shows a high-level view of intent-based network. Data-driven operations will be one essential in the cognitive networks.

Figure 5.4 shows a more complete deployment view, with cognitive network components both at the sites of the organisations developing AI solutions and at the TSP sites. The key components of the network include data ingestion components, Data Relay Gateway (DRG) which

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115

transfers data between the TSP and the domain of the developing organization, achievement of a clear separation of responsibilities, Data Operations (DataOps) environment for feature engineering, environment of Machine Learning Operations (MLOps), Intent Managers (IM) and Network Functions (NF). An observation from figure 5.4 is on the ownership of model trained in a federated way with multiple vendors involved having components at any site. The blog suggests that Data Relay Gateway (DRG) may be part of the answer to the question. The DRG is the functionality that enforces data transfer according to agreements covering legal and privacy aspects.

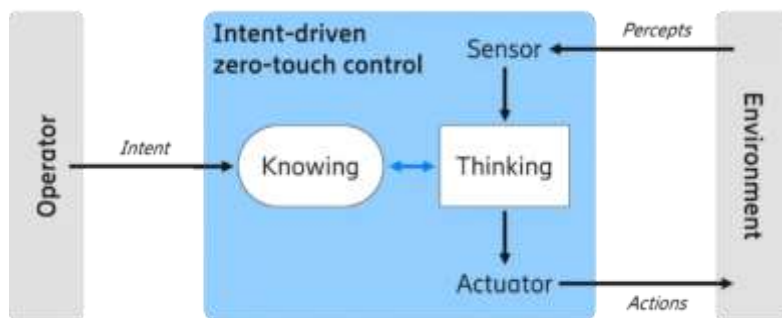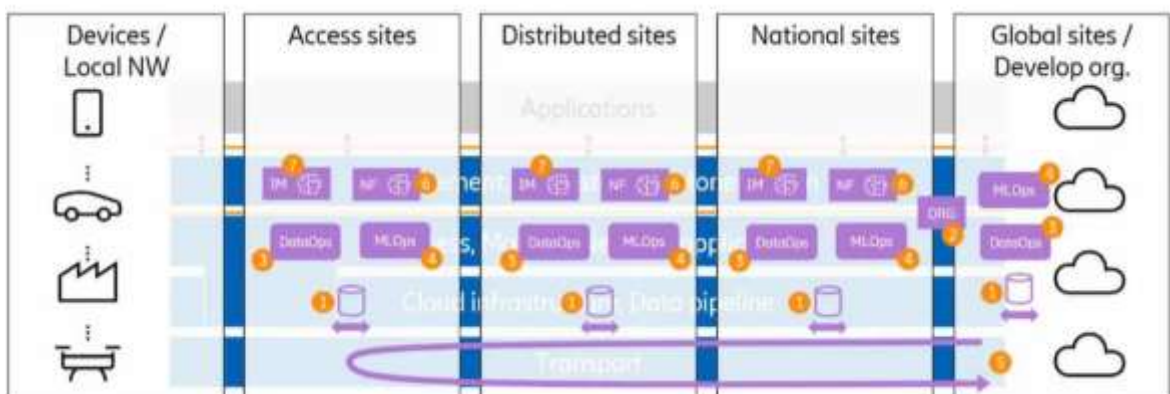**Figure 5.3:   High Level View of Intent Based Network**

Figure 5.4:   Deployment view - Components at the CSP and the developing organization's premises

5.5.5.   **Architecture for implementing ML in future networks:** IMT-2020

networks featured with diverse services, e.g., mobile internet, Internet of Things, cloud computing and other types of communication, will lead to the growth of data traffic and therefore would need proper management of data volume and transactions. In November, 2017, a Focus Group on Machine Learning i.e. (FG-ML5G) which includes Future Networks was created by ITU-T Study Group. It envisages to conduct an analysis of ML for future networks to identify relevant gaps and issues in standardization. In July 2020, the Focus Group completed its tasks and came out with standards and requirements for implementing ML in future networks including 5G. The Focus Group provided tool kits to implement machine learning in future networks. These tools were further employed to give an architectural framework for machine learning in future networks including IMT 2020. Some toolkits suggested by ITU include Framework for data handling which enables machine learning in future networks including IMT-2020[137], ML Sandbox, Machine learning function orchestrator (MLFO), ML Pipeline and ML Marketplace. A Whitepaper by 5G Americas[138] highlights that orchestration contributes to automation by coordinating and connecting the automated tasks and service flows across the network in multi-domain, multi-layer and multi-vendor scenarios. This may include scaling up/down for virtual function to maintain performance while maximizing utilization of available network resources. The paper also describes techniques for orchestration which include Zero Touch Network & Service Management (ZSM) and Multi-Access Edge Computing Orchestration. The analytics and ML may help in efficient operation of ZSM. The figure 5.5 shows the architecture for ML in the future components with its key components.

In this architecture, Machine learning function orchestrator (MLFO) plays key role to orchestrate the operations of machine learning

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[137] https://www.itu.int/rec/T-REC-Y.3174/en

[138] https://www.5gamericas.org/wp-content/uploads/2019/11/Management-Orchestration-and-Automation_clean.pdf

pipelines across the network to provide a managed AI/ML integration for the operator.

Figure 5.5:   Architecture for ML in future networks
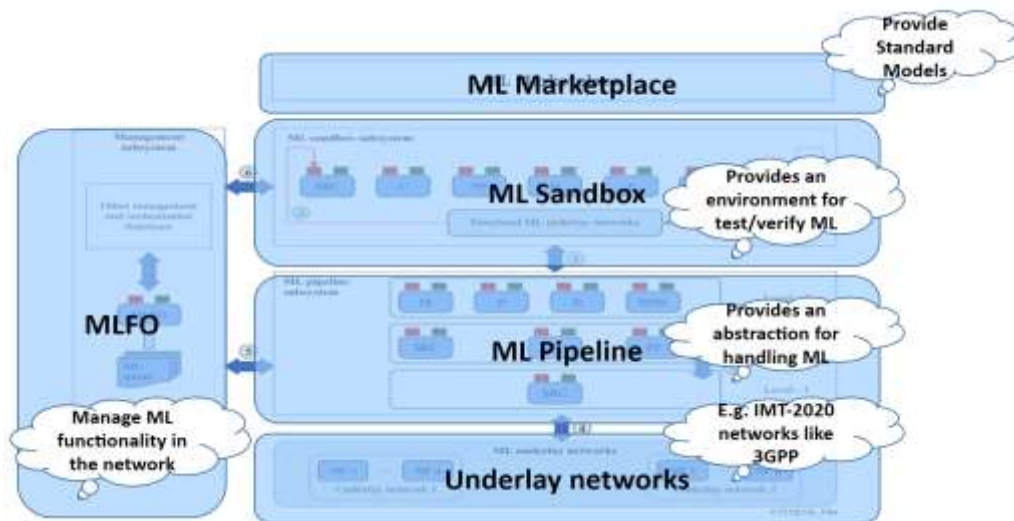
The combination of AI at Edge and FL involves multiple ML models performing their functions and at the same time learning and coordinating. Further, with the emergence of next generation mobile technologies, the number of such AI/ML models will increase tremendously, and for proper functioning there may be need of a mechanism for coordination and communication between the AI/ML models. In this case, the MLFO may help in coordinating and communicating between MLOps pipelines.

5.5.6. **Role of AI chips in AI at edge in end user devices:** The advancement in AI chips may further support adoption of AI at edge and FL in telecom sectors for handling privacy. A report by Deloitte[139] highlights that AI chips are physically smaller, relatively inexpensive, and use much less power and generate much less heat. This makes it possible to integrate them into handheld devices such as smartphones as well as non-consumer devices such as robots. By enabling these devices to perform processor-intensive AI computations locally, edge AI chips reduce or eliminate the transaction of large amounts of data to a

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[139]   https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2020/ai-chips.html

remote location, thereby delivering benefits in usability, speed, data security and privacy and also thereby reducing power requirements by telecom infrastructure to handle such large data. The AI chips may also enable the devices to train, test and evaluate the small AI models on the device itself. Thus, the AI chips may also address the computing infrastructure requirements for development of AI solutions. As discussed in Chapter 2, most of the device will be having AI chips for their functioning. The telecom industry may also work towards adoption of AI chips at each and every node to the network to enhance the performance of the network.

5.5.7. **Role of TinyML at edge:** As training of AI models requires high computing infrastructure and the computing capabilities of AI chips at edge devices may be limited, this poses restrictions of development of AI models at edge. In these cases, the emerging field of TinyML will address these concerns. A whitepaper by University of Oulu[140] also highlights that lightweight AI solutions are already needed at the mobile device level to increase autonomy and self-capabilities. TinyML[141] is broadly defined as a fast growing field of ML technologies and applications including hardware, algorithms and software capable of performing on-device sensor data analytics at extremely low power, typically in the mW range and below, and hence enabling a variety of always-on use-cases and targeting battery operated devices. TinyML is enabling a new class of low-latency, high-bandwidth applications. Researchers[142] studying TinyML have found ways to reduce model sizes, often through model architecture search, and ways to reduce computation requirements by lowering precision parameters (quantization) and byremoving low-utility weights (pruning), or by introducing weight compression schemes. The result is that ML models are finding yet another home in small, low-powered embedded devices. Following are some advantages[143] of TinyML:

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[140] http://jultika.oulu.fi/files/isbn9789526226774.pdf
[141] https://www.tinyml.org/
[142] https://www.bvp.com/atlas/the-evolution-of-machine-learning-infrastructure
[143] https://towardsdatascience.com/an-introduction-to-tinyml-4617f314aa79

i. **Low Latency:** Since the model runs on the edge, the data doesn't have to be sent to a server to run inference. This reduces the latency of the output.

ii. **Low Power Consumption:** As we discussed before, microcontrollers consume very little power. This enables them to run without being charged for a really long time.

iii. **Low Bandwidth:** As the data doesn't have to be sent to the server constantly, less internet bandwidth is used.

iv. **Privacy:** Since the model is running on the edge, your data is not stored in any servers.

As AI learning and model training is moving towards edge, the telecom sector will be one of the beneficiaries of TinyML. Thus, industry may explore the possibilities and applications of TinyML at edge.

5.5.8. Need to develop Operator Platform at Edge for Cross Sector Utilization

i. A paper[144] published by GSMA, highlights that there is a growing industry consensus that while consumers will be the biggest initial adopters of 5G, the enterprise segment offers significant incremental revenue opportunity for operators in the 5G era. Given the wide diversity of use cases that operators will be tasked to address from healthcare to industrial IoT, it seems logical for operators to create a generic platform that can package the existing assets and capabilities as well as the new capabilities such as Edge cloud, network slicing etc. that 5G makes available. (This will create necessary flexibility required by new breed of enterprise customers.

ii. This paper suggests that operators will collaborate to offer a unified 'operator platform'. This platform will federate multiple operator's edge computing infrastructure to give application providers access to a

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[144] https://www.gsma.com/futurenetworks/wp-content/uploads/2020/02/GSMA_FutureNetworksProgramme_OperatorPlatformConcept_Whitepaper.pdf

global edge cloud to run innovative, distributed, and low latency services through a set of common APIs. This common 'operator platform' may help developers of smart end user devices by avoiding the requirement to deal separately with many operators. This common 'operator platform' may also help in offering edge computing in a seamless manner even when user travel from one operator's network to another.

iii. This Operator Platform can also leverage, apart from other things, an enviable position for stringent security, data privacy, residency and sovereignty. Cloud capabilities will be treated as a subset of edge. It is expected that in future, enterprises will require in parallel a simple and universal way to interact with customers and new network and services capabilities. Operators will need to package their solutions as open platforms that can be used by enterprises to deliver services to their customers.

iv. There may be a need to have framework that would ensure users of the platform (developers and application providers) are involved at an early stage in the design and have their needs taken care of.

v. Operator Platform (OP) would enable an operator to place the solutions or applications of enterprises in a proximity to their customers. Exposed capabilities of Operator Platform can be used seamlessly across the federation footprint. Operator Platform may serve as an access point to external application providers for accessing network and service capabilities.

vi. The concept presented in the GSMA paper seems to be interesting and powerful way to build and enhance services in 5G era. Operators will play a key role to grant access to applications closer to the end user fostering the development of new services and solutions that make full use of 5G capabilities.

vii. Furthermore, this paper highlights that with the edge and platform concept, key enhancements would be needed to go beyond simple data

centers with distributed computing capabilities. Such enhancements may include, capability to federate operators so that edge computing is offered as a unified service by an Operator Platform and capabilities to select or reselect relevant edge computing node for optimizing the performance at a particular location of a cloud service user.

viii. This paper also highlights that operator may be required to go beyond the standard approach of defining common APIs and data models. As per this paper, operators should ensure technology development and its availability based on iterative models for software development instead of specification-based waterfall model. "More running code and less paper" is a recommended principle. It also suggests that operators should not work in isolation and rather they should engage with players that have already solutions or communities on Edge Cloud, moving from a pure Telco initiative to a wider industry initiative.

ix. The paper provides good examples of federation of use cases in its annexure. Use cases given in the paper mainly refers international scenarios while same concept may also be applied within a country. This concept may also be applied in case of public services where ecosystem of application providers and customers may be local in nature but their requirements may be contextualized as per needs. Footprint of Edge computing infrastructure and its capability may differ from one telco to another while requirements of the end users of the applications may be same or similar. With capabilities of Edge AI in protecting privacy and giving enhanced experience, concept of Operator Platform may be very useful for delivering future services in more equitable manner. With increased digital interactions, this concept may also enable framing data-driven public policies. In order to extract full value of this concept, there may be need to conduct experiments with the involvement of relevant stakeholders.

Issues for consultation

Q.21. **Whether the next generation telecom network architectures such as AI at edge, federated learning, TinyML or their combination can offer solutions to meet both privacy as well as intelligence requirements? Please justify your response with rationale and suitable examples, if any.**

Q.22. **What type of technological advancements are happening for running the AI models on the end user devices to overcome constraints in respect of processor, memory, battery etc.? Whether special tools, programming languages, and skills are required to be developed to build such AI models? Please justify your response with rationale and suitable examples, if any.**

Q.23. **Considering availability of new privacy preserving architectures as suggested in response to Q.19 and Q.20, what is the likelihood of emergence of new business and operational models? Whether such models will raise issues related to ownership and responsibilities? What do you suggest to address these issues? Please justify your response with rationale and suitable examples, if any.**

Q.24. **Whether the concept of "Operator Platform" would help in providing AI based solutions in a unified and more equitable manner? Apart from popular federated use cases of edge cloud federation, Cloud XR, Cloud Gaming, whether this concept may also be applied for public service delivery and in making public policies that are data-driven? Whether there is a need to take initiatives for developing and demonstrating advantages of concept of "Operator Platform"? If so, what steps and measures are suggested to launch such initiatives? Please justify your response with rationale and suitable examples, if any.**

5.6.   Build AI Specific Infrastructure for Telecom

5.6.1.   The computation requirements at each layer of network may be different as the AI models have to perform different type of operations. To fulfil such demands, organisations are adopting Graphical Processing Unit (GPU) or Tensor Processing Unit (TPU) as an efficient computing infrastructure. Further, the adoption of GPU, TPU may also vary based on the area of application as GPU[145] shows better flexibility and programmability for irregular computations, while TPU is highly-optimised for large batches and Convolution Neural Networks (CNNs) and has the highest training throughput. Facebook[146] also published that in 2017, it had designed first generation of high computing infrastructure which has 22,000 NVIDIA V100 Tensor Core GPUs in a single cluster. Now, Facebook (Meta) is developing AI Research SuperCluster (RSC)[147] which will increase AI training performance by more than 2.5-fold. In India, PARAM Siddhi-AI[148] is high-performance computing-artificial intelligence (HPC-AI), built on the NVIDIA DGX SuperPOD reference architecture networking. Thus, organisations are working towards fulfilling the demand of computing infrastructure for different level of applications by developing AI specific infrastructure.

5.6.2.   Various initiatives taken by other jurisdictions and India to provide necessary infrastructure for AI models, are discussed below in detail:

    i.   **France:** The AI-specialized high-performance computer infrastructure Jean ZAY, was inaugurated in early 2020. In support of the national strategy, Jean ZAY[149] will drive France's AI and HPC efforts. The computer will be part of GENCI, the French national infrastructure for HPC resources and facilities. DataDirect Networks is also a supporting partner in providing flash storage technology that will enable a

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[145] https://analyticsindiamag.com/tpu-vs-gpu-vs-cpu-which-hardware-should-you-choose-for-deep-learning/

[146] https://ai.facebook.com/blog/ai-rsc/

[147] https://ai.facebook.com/blog/ai-rsc/

[148] https://analyticsindiamag.com/a-complete-list-of-indian-param-supercomputers/#:~:text=PARAM%20Siddhi%2DAI-,PARAM%20Siddhi%2DAI%20is%20a%20high%2Dperformance%20computing%2Dartificial,4.6%20Pflops%20Rmax%20(Sustained).

[149] https://www.hpcwire.com/2019/01/22/france-to-deploy-ai-focused-supercomputer-jean-zay/

read/write capacity of more than 300 GB per second. Thus, the supercomputer will be helpful in improving computing performance and storage requirements of AI operations.

ii. **United Kingdom:** The UK initiated policy interventions for the development of trustworthy and qualitative data infrastructure. This data infrastructure will support the data handling processes and safe and secure transfer of data with others. Thus, for supporting the development of digital and telecommunication infrastructure, UK Govt. also took following initiatives[150]:

   a. The National Productivity Investment Fund has been increased to £31 billion in 2017 in order to support among others the development of a digital infrastructure;
   b. UK's strategy mentions a public investment of £1 billion of public investment to boost the digital infrastructure, which includes £176 million for 5G and £200 million for full-fibre networks;

iii. **Germany[151]:** Cornerstone initiatives in Germany's preparation for the next-generation data infrastructure are the GAIA-X project and the Federal Government Data Strategy. The objective of the GAIA-X project, initiated by Germany and France, is to create a secure, federated data system that meets the highest standards of digital sovereignty while promoting innovation.

iv. **India:** The NITI Aayog proposed to establish India's own AI-first compute infrastructure. It is aimed to facilitate and speed up research and solution development for solving India's societal challenges using high performance and high throughput AI-specific supercomputing technologies. The approach paper[152] on AIRAWAT (AI Research, Analytics & knoWledge Assimilation plaTform) introduced a cloud-based AI-specific infrastructure to support varieties of AI workloads

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[150] https://knowledge4policy.ec.europa.eu/ai-watch/united-kingdom-ai-strategy-report_en
[151] https://knowledge4policy.ec.europa.eu/ai-watch/germany-ai-strategy-report_en#aireport
[152] https://www.niti.gov.in/sites/default/files/2020-01/AIRAWAT_Approach_Paper.pdf

and Learning frameworks for user choices. The proposed architecture, with composite compute and storage infrastructure, allows maintaining large data sets (thus eliminating the need for separate data centres and addressing data integrity concerns), and proximity of computing facilities for efficient processing of data-intensive tasks viz. training of algorithms on large (both number and size) datasets.

5.6.3. The above paras illustrate that to train and develop an AI model, there is a need of AI specific computing infrastructure. The advanced hardware architectures are accelerating computation capabilities on specific use cases for example[153], GPU has become the de facto hardware for computer vision applications, Programmable and power-efficient Field Programmable Gate Arrays (FPGAs) for chip prototyping and custom use cases. However, a mosaic of low-level software tools for ML and embedded systems is empowering companies to harness these hardware improvements. OpenAI's Triton library, for example, supplants Compute Unified Device Architecture (CUDA) and offers highly-efficient GPU programming. For mass production, chip designers also have an Application-Specific Integrated Circuit (ASICs) and associated Hardware Design Languages (HDLs) like Verilog at their disposal. These improvements have indeed helped support the rapid exponential growth in computing capabilities which is necessary for training of today's AI models.

5.6.4. **Democratization of Models:** Further, ML ecosystem[154] have witnessed tremendous progress in last few years. The success of large models trained on expansive datasets i.e. foundational models has unlocked high performance across ML models. The coalescence of these foundational models (e.g. BERT, CLIP, the GPTs, Gopher) has democratized access to high-quality, generic architectures. Also, the fine-tuning of foundational models can lead to high performance for downstream tasks. The emergence of foundational models creates network effects i.e. improvements to one model can often flow into its

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[153] https://www.bvp.com/atlas/the-evolution-of-machine-learning-infrastructure
[154] https://www.bvp.com/atlas/the-evolution-of-machine-learning-infrastructure

fine-tuned or derived models. The homogenization of models and growing AutoML paradigms also allow some degree of standardization in the ML stack and process, which enables adoption and further innovation of these models.

5.6.5.   The above illustrations indicate that nations are investing to build foundational models which requires huge investments. When such powerful models like GPT-3, BERT, CLIP and Gopher exist, it is best to train other models on them. This will reduce the effort to build models from scratch and thereby reduce cost and time. It also brings some degree of standardisation in AI modelling. Thus, to accelerate adoption of AI in telecom sector, the industry may use the benefits of such models to train their AI models by fine-tuning or deriving from foundational models. Similar approaches are useful in development of large AI models by fine tuning or deriving models specific for country requirements.

Issues for consultation

Q.25.   **Whether there is a need to create AI-specific infrastructure for the purpose of startups and enterprises in the telecom sector to develop and run AI models in an optimised manner? Whether such an infrastructure should cover various real-world scenarios such as cloud AI, edge AI and on-device AI? Please justify your response with rationale and suitable examples, if any.**

Q.26.   **Whether the emerging trends of development of foundational AI models such as GPT-3, Gopher etc. are leading to democratisation of AI space by offering fine-tuned or derived AI models? Whether such a trend will also help in reducing costs for the AI developers? Whether similar approach will help in development of large-scale AI**

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model for the telecom sector? Please justify your response with rationale and suitable examples, if any.

5.7. Mechanisms for Experimentation and Demonstration

5.7.1. Technology has always been a constant source of uncertainty, risks, changes and in many cases disruption. Complexity, uncertainty and the fast pace of the innovation process generate a panoply of regulatory challenges. Technology like AI also poses complexities, risks or constraints such as non-compliance of regulatory regimes, loss of direct control and harm to customers etc. in its adoption. Thus, the operators in telecom sector may have risks in adopting these technologies for live networks. Further, the operators can develop and test their AI solution on the live network. However, the other players in the ecosystem who desire to develop the AI solutions for the industry may not be able to develop an optimal solution due to non-availability of efficient live network for testing and demonstration. Further, development of an optimal solution requires to consider all the aspects of the network before deploying it live, which requires an environment which can provide similar conditions as available in a live network to test and design an optimal solution. Thus, there is a need to develop solutions which best fit the above requirements for testing and demonstration. Following are the mechanisms which can help in experimentation and demonstration of AI solutions.

5.7.2. **Regulatory Sandbox:** The regulatory sandbox may address the complexities and risks associated with deployment of AI solutions. It can also provide necessary environment to test and demonstrate the AI solutions for the industry. Further, there is a need to protect developers during experimentation stage, from any probable violation of existing regulations. It would also be helpful for policy makers to review existing regulations and address such concerns alternative ways. Creation of Regulatory Sandbox may be part of such a setup. AI Regulatory Sandbox provides a controlled

environment that facilitates the development, testing and validation of innovative AI systems for a limited time before their live deployment. It also reduces regulatory burden and facilitates experimentation to improvise and boost confidence of operators in AI solutions while deploying in live networks.

i. Globally, following countries have proposed to establish regulatory sandboxes for this purpose:

   a. The European Union[155] in its AI Act (AIA) proposed a common framework for AI regulatory sandboxes across Europe to ensure that the regulatory framework is innovation friendly, future-proof and resilient to disruption.

   b. In May 2020, Colombia's Regulation Communications Commission (CRC) introduced a regulatory sandbox[156] for communication services. Colombia Data Protection Authority launched an innovative regulatory Sandbox on privacy by design and by default in AI projects.

   c. The UK Information Commissioners Office, ICO[157] introduced the Sandbox service to support organisations which are developing products and/or services that use personal data in innovative and safe ways and where such products and/or services deliver a potential public benefit. In order to develop the Sandbox, the ICO initially launched the Sandbox as a beta phase, for an initial group of participant organisations in 2019 - 2020.

   d. The Norwegian Data Protection Agency[158] has introduced a regulatory sandbox following the British model. The sandbox establishes a project environment for AI, where private and

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[155] https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence
[156] https://www.crcom.gov.co/es/pagina/sandbox-regulatorio#guia-digital
[157] https://ico.org.uk/media/for-organisations/documents/2618905/nhs-digital-regulatory-sandbox-final-report.pdf
[158] https://dataethics.eu/sandbox-for-responsible-artificial-intelligence/

public companies can get free guidance on personal data protection.

    ii. Following may be the possible objectives for adoption of regulatory sandboxes:

        a. To foster AI innovation by establishing a controlled, safe and testing environment during development and pre-marketing phase.

        b. To enhance legal certainty for innovators and the competent authorities' oversight, and understanding of the opportunities, emerging risks and the impact of AI use.

        c. To accelerate access to markets which includes removal of barriers for small and medium enterprises (SMEs) and start-up.

    iii. Experimentation mindset is the key to build confidence in both users i.e. telecom operators and telecom subscribers who are directly or indirectly impacted by those solutions. The adoption of regulatory sandbox may help to achieve the goal of AI through experimentation. It should be explored whether regulatory sandbox can provide means to demonstrate the strength of privacy preserving techniques, since it could help in building trust. Thus, the regulatory sandbox may require to be designed and developed for AI in telecom sector along with framing necessary terms and conditions.

5.7.3. **Evolving Future Business Models-Concept of Lighthouse:** In order to reduce cost burden and ease out process for experimentation, a campus with suitable infrastructure may be made available to the experimenter to come and test his/her innovative products or solutions. This concept may be built on similar lines as adopted for accelerating adoption of Industry Revolution 4.0 (4IR). In 2016, the World Economic Forum (WEF)[159] came up with a concept of Lighthouse

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[159] https://www.weforum.org/agenda/2020/09/manufacturing-lighthouse-factories-innovation-4ir/

in order to accelerate adoption of Industry Revolution 4.0 (4IR). Lighthouse shows the way demonstrating how digitally infused operations extend beyond productivity gains for creating a base for sustainable, and profitable growth. It yields increased speed to market through customizable product development which is informed by a better understanding of customer demands; meanwhile, it boosts productivity of both assets and people. While conventional wisdom might presume that this kind of transformation would come at exorbitant cost, lighthouses are showing the opposite trend.

The concept of lighthouse may also be adopted with suitable modifications to accelerate adoption of AI related use cases in the telecom sector. The adoption may incorporate design thinking concepts while building a shared infrastructure available to experimenters to develop AI solutions by involving all relevant stakeholders. Focus of the campus may be to provide test infrastructure and offer opportunities for relevant stakeholders and startups to develop new business and operational models. This may also be helpful to departments and ministries including regulators for understanding and identifying changes needed in the existing policies and regulations or for introducing new regulations.

Issues for consultation

Q.27. Whether there is a need to establish experimental campuses where startups, innovators, and researchers can develop or demonstrate technological capabilities, innovative business and operational models? Whether participation of users at the time of design and development is also required for enhancing the chances of success of products or solutions? Whether such a setup will reduce the burden on developers and enable them to focus on their core competence areas? Please justify your response with rationale and suitable examples, if any.

> **Q.28.** **Whether experiments are required to be backed by regulatory provisions such as regulatory sandbox to protect experimenters from any violation of existing regulations? Whether participation of government entities or authorities during experimentation will help them to learn and identify changes required in the existing regulations or introducing new regulations? Please justify your response with rationale and suitable examples, if any.**
>
> **Q.29.** **In response to Q.27 and Q.28, whether establishing such a campus under government patronage will enable easy accessibility of public resources such as spectrum, numbering and other resources to the researchers? Whether it would be in mutual interest of established private players as well as startups, innovators and enterprises to participate in such experiments? Please justify your response with rationale and suitable examples, if any.**

5.8. Conducting challenge-based program

5.8.1. The risks and constraints with technologies are being addressed by various organisations/companies by organising challenge-based programs. These programs help in improvising the solutions or products by allowing different stakeholders to participate and to demonstrate their products or provide ideas on the solutions. Conducting challenge-based programs not only resolves the constraints but also helps in building trust on the AI solutions. If the participants are able to disrupt the AI solution, the operator needs to further work on the AI solution to improve its capabilities before launching in a real environment. This process helps in developing an optimal AI solution.

5.8.2. **Conducting challenges for problem statements:** In the Graph

Neural Networking Challenge[160] organised by ITU under the initiative of "AI/ML in 5G Challenge[161]", participants were asked to train their GNN models in small network scenarios (up to 50 nodes), and then test their accuracy in networks of increasing size say, up to 300 nodes. Solutions with better scalability properties were announced as winners. In another problem statement[162] under the same initiative, ITU invited innovators worldwide to develop AI/ML solutions for 5G networks, on the theme "How to apply ITU's ML architecture in 5G networks". Teams were enabled to create, train and deploy ML models to solve real world problems based on standardised technologies developed for ML in 5G networks. Some other problem statement hosted by ITU under "AI/ML in 5G Challenge" are mentioned in table 5.2 below:

Table 5.2:   Challenges hosted by ITU

Challenge	Problem Statement	Description
ITU AI/ML 5G Challenge[163] 2022	Federated Traffic Prediction	Usage of federated learning tools to predict traffic in cellular networks from real measurements
	Graph Neural Networking Challenge	To explore a data-centric approach to develop Network Digital Twins by producing a training dataset that results in better performance of the target GNN model
	Beam Classification with DeepBeam	To create a classifier for transmitting beams out of a codebook using neural networks with the DeepBeam Dataset
	Depth Map Estimation in 6G	To propose an AI/ML algorithm that reconstructs the depth map of an indoor environment from mmWave MIMO channel impulse responses and depth map representation
	Network failure prediction	To create AI/ML models for predicting network failures using time-series data consisting of thousands of metrics in 5G core network

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[160] https://aiforgood.itu.int/event/the-graph-neural-networking-challenge-2021-scaling-up-gnns-to-large-real-world-networks/

[161] https://aiforgood.itu.int/about-ai-for-good/aiml-in-5g-challenge/

[162] https://www.itu.int/en/ITU-T/AI/challenge/2020/Pages/default.aspx

[163] https://aiforgood.itu.int/about-ai-for-good/aiml-in-5g-challenge/

	Location Estimation Using RSSI	To develop an AI/ML-based localization algorithm/technique that accurately estimate the position of a receiver based on RSS Information (RSSI)
	Behavioral modeling for energy efficiency	To bring AI algorithms into behavioral modeling of power amplifiers, helpful for developing highly efficient 5G wireless communication systems
	Throughput Prediction in Wi-Fi networks	To predict achievable throughput with the help of ML that a subset of Access Points transmitting at the same time can achieve
	Data Generation using GANs	To generate synthetic observability data using GANs for Telco-Cloud Infrastructure Metrics to solve the problem of dataset unavailability for AI/ML researchers
	Build your own Closed loop	To collaboratively create a crowdsourced, baseline representation for AN closed loops (controllers) as a proof of concept
	Beam Prediction Challenge	To design machine learning-based models that can adapt to and perform accurate sensing-aided beam prediction at an entirely new location
	Classification of network users	To classify each user and accurately distinguish between users with bad experience and users with good experience using ML/DL methods
ITU AI/ML 5G Challenge[164] 2021	Delivery route optimization	To optimize the delivery route planning in the transportation network
	WALDO (Wireless Artificial Intelligence Location DetectiOn)	To propose an AI/ML algorithm that estimates the location of moving targets, e.g. people, given a set of training dataset consisting of received 802.11ay packets at different SNR levels and the corresponding wireless channel information.
	Multidevice localization with mmWave signals in a factory environment	To addresses the problem of estimating the 3D position and orientation of active devices in a factory
	Graph Neural Networking Challenge	To create a scalable network digital twin using GNN
ITU AI/ML 5G	Alarm and prevention for public health emergency	To focuses on epidemic surveillance, spread monitoring, precise prevention, resource allocation, effect evaluation by telecom users' tracking data and DPI information

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[164] https://aiforgood.itu.int/about-ai-for-good/aiml-in-5g-challenge/challenge-2021/

Challenge[165] 2020	based on telecom data	
	Using weather info for radio link failure (RLF) prediction	To predict the RLF from weather forecast as well as radio link (RL) performance (for a given frequency band)
	5G+AI (Smart Transportation)	Intelligent Vehicles for unstructured environments
	Improving experience and enhancing immersiveness of Video conferencing and collaboration	To improve perceptual immersiveness, algorithms need to be designed to communicate a person's peripheral characteristics and interaction with the surroundings to communicate important information related to the event.
	Privacy Preserving AI/ML in 5G networks for healthcare applications	To demonstrate strength of Privacy-Preserving AI techniques such as Homomorphic Encryption, Differential Privacy, etc in healthcare applications
	MLFO capabilities	To demonstrate MLFO capabilities via reference implementations

In these problem statements, it may be observed that the dataset used in the training and testing of AI/ML models, while in a challenge-based program, experimenting with a test-bed or while launching a new product, the dataset should be relevant and representative of the user demographic and surrounding environment as well as indicative usage patterns. The complete procedure from the accuracy of predictions to the final inferences drawn, should be optimized for the benefit of the consumers. The problem statements and optimal solutions may vary in Indian context.

5.8.3. **Bounty Program**: A bounty program is a deal offered by many websites, organisations and software developers wherein individuals receive recognition and compensation for reporting bugs, especially those pertaining to security exploits and vulnerabilities. These

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[165] https://aiforgood.itu.int/about-ai-for-good/aiml-in-5g-challenge/challenge-2020/

programs allow the organisations to discover and resolve issues in products or solutions before the general public is aware of them thus, preventing incidents. Bug bounty programs have been implemented by a large number of organisations. A Chinese telecom service provider, ZTE, launched a bug-bounty program[166] to encourage security researchers and organisations worldwide to identify vulnerabilities in its products and services. Apple Security Bounty[167], as part of Apple's commitment to security rewards researchers who share critical issues and the techniques used to exploit them.

5.8.4. Similar approach may be adopted in the telecom sector for adoption of AI, where the telecom operators may organise, challenge-based programs or bounty programs to resolve the issues and improve the performance of the AI solutions in the network. This may provide a platform to demonstrate innovative solutions and give opportunities for others to find vulnerabilities or issues in the AI solutions. Solution providers may come up and demonstrate to prove that there are techniques strong enough to protect user privacy while harnessing their data. Such demonstrations build trust on the AI solution so developed and bring recognition to operator's use of smart solutions and products to improve telecom networks. Further, while conducting the challenge or bounty programs, the industry should promote the usage of indigenous datasets. These datasets can be collected or generated based on the requirements and the nature of the program. Collaboration of telecom with different sectors viz. health, transport, finance etc. may significantly help in achieving the desired results.

Issues for consultation

Q.30.   Whether active participation in the international challenge programs such as ITU AI/ML 5G challenge will help India's telecom industry in adopting AI? Whether similar programs are also required to be launched at the national level?

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[166] https://www.zte.com.cn/global/about/news/20201023e1.html
[167] https://developer.apple.com/security-bounty/

> **Whether such programs will help to curate problem statements or help in enabling, creating, training and deploying AI/ML models for Indian telecom networks? What steps or measures do you suggest to encourage active participation at international level and setting up of such programs at national level? Please justify your response with rationale and suitable examples, if any.**
>
> **Q.31.   Whether AI/ML developers should launch bounty programs to establish trust in the public about robustness of measures taken by them to protect privacy in their products or solutions? Whether conduction of such programs will help companies or firms to improve their products or solutions? Whether such programs should be conducted under the supervision of the government or an institution established/assigned for this purpose? Please justify your response with rationale and suitable examples, if any.**

5.9.   Adoption of MLOps (Machine Learning Operations) and Tooling[168]

5.9.1.   A Machine Learning Operations (MLOps) environment is where ML models are developed, trained, validated and stored. Training is based on data from the DataOps feature store. Note that training data may also involve feedback from models that are already up and running. The MLOps environment may benefit from hardware acceleration such as Graphics Processing Units (GPUs) and Tensor Processing Units (TPUs).

5.9.2.   A new generation of tooling for hardware specifications and compiler optimizations have helped researchers surpass ML benchmarks and reduce model training costs.

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[168] https://www.bvp.com/atlas/the-evolution-of-machine-learning-infrastructure

5.9.3.   But this has resulted in rapid fragmentation across the stack. The modern execution stack (the ML compiler, runtime, kernels, and associated tooling), Developer-facing ML frameworks (PyTorch, Tensorflow) and associated compilers and intermediate representations (LLVM, XLA, MLIR) evolved independently from hardware and kernel libraries (Intel's OpenVino, Nvidia's CUDA, and CuDNN). This makes interoperability and compatibility an issue across the MLOps pipeline.

5.9.4.   Companies looking to deploy their models across edge and cloud targets using non-standard targets such as mobile phones or custom ASIC are burdened with bespoke integration challenges. This is leading them to unify these technologies and standardize the operations pipeline. For example, Apache TVM (OctoML) and Modular.ai are building towards a generic execution framework offering hardware-specific optimized models.

5.9.5.   The industry push to unify these software stacks is often coupled with attempts to optimize them. Across the MLOps pipeline, training remains a priority for optimization. Training workflows, relative to inference, require many more cycles on bare-metal GPU servers. Considering this, bare-metal compute lacks efficiency. Many workloads only use 20 or 30 percent of machine resources yet require a lease on the entire GPU. To increase utilization, startups such as Run:AI, Deci.ai, Neural Magic, and OctoML are applying a variety of intelligent approaches, such as hyperparameter tuning, pruning, sparse regularization, and CPU-based parallelism, among others to optimize the model, along with dynamic resource provisioning and allocation.

5.9.6.   Today, building a scalable backend for ML involves provisioning, integrating, and scaling many tools for data versioning and labeling, as well as for feature stores, model management, and monitoring, etc. This requires considerable engineering effort and time, slowing the

development. A broader standardization in the MLOps lifecycle can be expected in the near future.

5.9.7. Such capabilities of MLOps and tooling may be required to be explored and utilised for development and optimization of AI solutions and products in the telecom sector.

Issues for consultation

Q.32. **Whether the telecom industry is required to adopt a Machine Learning Operations (MLOps) environment to develop, train, validate and store ML models? Whether there is also a need to establish a DataOps feature store to help MLOps for training purposes? What standardisation is required in terms of interoperability and compatibility for MLOps to function in a federated manner? Please justify your response with rationale and suitable examples, if any.**

5.10. Making AI Workforce

5.10.1. As discussed in chapter 4, lack of skill impedes overall innovation. The need for skills for AI is also considered by various countries. Following countries have started working towards improving skilling and reskilling of workforce for AI:

i. **United States of America:** In 2021, USA passed an Act, "National Artificial Intelligence Initiative Act of 2020[169]". The purpose of the act was to prepare the USA workforce for integration of AI systems across all sectors of the economy and society. Federal R&D agencies are supporting many fellowship and scholarship programs for graduate and postdoctoral studies in AI.

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[169] https://www.congress.gov/116/crpt/hrpt617/CRPT-116hrpt617.pdf#page=1210

ii. **European Union:** European Strategy on AI[170] published in 2018 envisages preparation for socio-economic changes brought about by AI by encouraging modernising education and training systems, nurturing talent and anticipating changes in the labour market.

iii. Similarly, Countries like the United Kingdom, Finland, France, Germany, Norway, Australia, United Arab Emirates, Canada, and Singapore are also working towards building a skilled workforce to meet the requirement for AI. Most of the countries have made AI as a part of their educational curriculum. Some countries like the UK, Finland, and Norway have introduced higher education and post graduate courses in this field. Some countries have introduced apprentice programs and vocational training for teachers to learn and understand AI. Countries like UK, Australia and Denmark have committed towards strengthening their capability in AI and ML through funding.

5.10.2. Further, as per the report[171] of 2021 published by Stanford University, the number of courses to build or deploy a practical AI model on the undergraduate and graduate levels has increased by 102.9% and 41.7%, respectively, in the last four academic years. Also, the share of new AI PhDs who chose industry jobs increased by 48% in the past decade, from 44.4% in 2010 to 65.7% in 2019. As per the report[172] of 2022 published by Stanford University, India led the world in the rate of AI skill penetration by 3.09 times the global average from 2015 to 2021 followed by the United States (2.24) and Germany (1.7). After that came China (1.56), Israel (1.52), and Canada (1.41). Further, India and the United States had the highest relative AI skill penetration across the board leading other countries or regions in skill penetration rates in software and IT services, hardware and networking, manufacturing, education, and finance.

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[170] https://ec.europa.eu/transparency/documents-register/api/files/COM(2018)237_0/de00000000142394?rendition=false
[171] https://aiindex.stanford.edu/wp-content/uploads/2021/11/2021-AI-Index-Report_Master.pdf
[172] https://aiindex.stanford.edu/wp-content/uploads/2022/03/2022-AI-Index-Report_Master.pdf

5.10.3. To develop skills for AI, various graduation/post-graduation courses are provided in many universities. However, to bring new use cases in any sector, it requires sector-specific knowledge and skills as part of the training. For example, there are various programming languages used for AI such as Python, R, LISP, Java, C++, Prolog, Go and Julia etc. and different operations require different programming language. In the case of telecom, network engineers typically do not have background of AI that includes mathematical training and experience that is essential in AI, for example data modelling and evaluation, software engineering and system design, ML algorithms and libraries. Also, AI experts may not have technical knowledge of the network. Thus, recruiting people with the right skills is a challenge. A PWC survey report[173] states that 28% of the firms consider training and recruiting skilled professionals who can work with AI systems, a hurdle.

5.10.4. In the telecom sector too, there may be a need to build AI workforce to accelerate adoption of AI. For this purpose, a clear roadmap on capacity building and skilling may be required to be formulated. This roadmap may include an assessment drive to identify professionals with requisite skills in the telecom sector. This assessment will help in understanding where does the telecom sector stands in terms of skilled workforce. This will also guide industry to work in particular areas and direction. After the assessment drive, the roadmap may include upskilling the current workforce to acquaint with use of emerging technologies and attracting new talent to work in the telecom sector. There is also a need to introduce new curriculum related to AI in telecom at graduation level to build AI workforce.

5.10.5. It has also been observed that some organisations and companies have been organising Bootcamps to impart better skills to their employees to improve the overall performance of the organisations. For example, MIT[174] launched a bootcamp program to impart

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[173] https://www.pwc.in/assets/pdfs/data-and-analytics/ai-an-opportunity-amidst-a-crisis.pdf
[174] https://bootcamps.mit.edu/

education, experience by on the job learning. On similar lines, the industry may also organise bootcamp programs to build workforce for new technologies. Stanford University[175] also launches Design Thinking Bootcamps to learn and apply skills to solve real business challenges. On a similar line, the industry may explore to launch bootcamp programs for AI and ML to build students and employees for development of solutions or products on AI in telecom sector.

Issues for consultation

Q.33. **Whether active participation in the international bootcamp programs such as MIT Bootcamps, Design Thinking Bootcamp by Stanford University etc. will help India's telecom industry workforce to find international developers community, navigate challenges and learn from experiences of others? Whether similar programs are also required to be launched at the national level? What steps or measures do you suggest to encourage active participation at the international level and setting up of such programs at the national level? Please justify your response with rationale and suitable examples, if any.**

Q.34. **Whether the courses or programs related to AI/ML currently being offered by various institutions and universities in India are adequate to meet the capacity and competence required to develop and deploy AI solutions or products in the telecom networks? If not, what additional steps or measures are suggested to fill the gap? Please justify your response with rationale and suitable examples, if any.**

5.11. Accreditation

5.11.1. Building trust on AI systems as a whole may be one of the key enablers for adoption of AI as it may address the concerns of risk or challenges

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[175] https://www.gsb.stanford.edu/exec-ed/programs/design-thinking-bootcamp

associated with AI. For building trust, the organisations and the Government stresses on the process of accreditation that would go a long way towards increasing public trust in AI. The accreditation of AI solutions is considered a possible key requirement for promoting the use of AI systems in adoption in various sectors. In addition, it can create confidence among citizens, lead to better products and influence the national and international market dynamics. In order to prevent accreditation procedures from becoming an obstacle to innovation, it is necessary to guarantee certain standards of AI systems, avoid over-regulation, enable innovation and initiate new developments in AI application. Accreditation certifies genuine AI solutions and products. It also builds trust during procurement of AI solutions and services.

5.11.2.   Following countries have proposed for accreditation of AI products and solutions to build trust on the AI:

i.   **European Union**: The European Economic and Social Committee[176] (EESC) suggests that the EU should develop a certification for trustworthy AI applications, to be awarded by an independent body after testing the products for key requirements such as resilience, safety, absence of prejudice, and discrimination or bias.

ii.   **Singapore**: Singapore-based AI companies are being accredited by IMDA under the initiative Accreditation@SGD[177].

5.11.3.   From the above discussion, it may be concluded that there is a need for accreditation of AI solutions or products developed by operators, solution providers and other players in the telecom sector. The process of accreditation may involve fulfilment of certain requirements that makes the AI solutions more trustworthy. For the purpose of accreditation, an entity or institution may be directed to frame

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[176] https://www.eesc.europa.eu/en/news-media/news/eesc-proposes-introducing-eu-certification-trusted-ai-products
[177] https://www.imda.gov.sg/programme-listing/accreditation-at-sgd

guidelines for accreditation of AI solutions or products.

Issues for consultation

Q.35. **Whether establishing a system for accreditation of AI products and solutions will help buyers to purchase such solutions or products? If yes, what should be the process of accreditation and who should be authorised or assigned with the task of accrediting such products or solutions? Please justify your response with rationale and suitable examples, if any.**

5.12. Procurement of AI Solutions or Products

5.12.1. Governments are likely to use the opportunities offered by AI to improve service delivery to the public at large and use AI as policy tools to stimulate the economy. AI has the potential to vastly improve governance and meet the needs of citizens in new ways, ranging from traffic management to healthcare delivery and settling tax compliances submitted by taxpayers to detect tax evasion. In the telecom sector also, AI has vast potential and opportunities as highlighted in Chapter 3. Various countries and organisations have been working to handle challenges and risks of AI. In India, NITI Aayog has also been working to operationalise the principles of responsible AI to address these risks. However, there is also a need for procurement mechanisms of AI solutions to safeguard the public from any impact by AI solutions being adopted. Various organisations and Countries have been working on procurement of AI products or solutions. Some of these are listed below:

   i. The **World Economic Forum**, in partnership with Deloitte and the UK government's Office for Artificial Intelligence, has developed a toolkit[178] to assist public sector organisations

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[178]https://www2.deloitte.com/ca/en/pages/deloitte-analytics/articles/guidelines-ai-procurement-government.html

seeking to procure AI solutions. The goals are as under:

 a. To help public sector organisations to create clear specifications that address concerns of bias, privacy, accountability, transparency, and proportionality

 b. To build dynamic and competitive AI marketplace

 c. To establish responsible AI practices

 ii. **Canada** has developed a similar framework[179]. The framework establishes a pre-qualified list of suppliers who meet all of the mandatory criteria to provide Canada with responsible and effective AI services, solutions or products.

5.12.2. Thus, to safeguard the public from any impact of AI solutions or products adopted in the telecom industry, there is a need to frame procurement mechanisms of AI products or solutions. It will also help in connecting with genuine suppliers. Thus, for the purpose of procurement of AI solutions or products, an entity or body may be directed or formed to frame the guidelines for procurement.

5.12.3. Further AI can also be leveraged in the process of procurement itself as this process gathers data on clients, spend, transactions, pricing, suppliers, contract details etc. Similarly, every stage of the supply chain has incoming and outgoing data that affects the product journey. Also, some review tasks in procurement are so time-consuming that data is only really looked on quarterly or biannual basis. Most of the organisations possess disparate data obtained from multiple enterprise-wide systems. The adoption of AI can bring together and identify synergies among them. Identifying patterns and anomalies is how AI get the most out of the data.

Adoption of AI in procurement process may help the entities, agencies, governments in making better decisions by identifying new

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[179] https://buyandsell.gc.ca/cds/public/2018/09/21/5e886991ecc74498b76e3c59a6777cb6/ABES.PROD.PW__EE.B017.E33817.EBSU001.PDF

opportunities, improving operations, automating manual tasks, freeing up time, capturing or applying scarce knowledge, identifying new suppliers or markets and optimizing supplier relationships. However, deploying AI in procurement process may require the guidelines to be followed to have a standard Code of Conduct for adoption.

Issues for consultation

Q.36.   Whether creating a framework to prepare a list of prequalified suppliers of AI products or solutions will help industry including government agencies to procure AI products or solutions? Whether there is a need to formulate a standard Code of Conduct or guidelines for AI related procurements? What should be the typical elements of such a Code of Conduct or guidelines including guidelines on trusted source and who should be tasked to formulate such a Code of Conduct or guidelines? Please justify your response with rationale and suitable examples, if any.

5.13.   Compendium of Toolkits and Use Cases

5.13.1.   In January 2019, Singapore released its first edition of the Model AI Governance Framework[180], which provides detailed and readily implementable **guidance** to private sector organisations to address **key ethical and governance** issues when deploying AI solutions. Infocomm Media Development Authority (IMDA) and Personal Data Protection Commission (PDPC) Singapore, partnered with the World Economic Forum Centre to develop the Implementation and Self-Assessment Guide for Organisations (ISAGO) in January 2020. Its purpose was to help organisations to assess the alignment of their AI governance practices with the Model Framework. It also provides an

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[180] https://ai.bsa.org/wp-content/uploads/2019/09/Model-AI-Framework-First-Edition.pdf

extensive list of useful industry examples[181] and practices to help organisations implement the Model Framework. The framework also translates principles into pragmatic measures that businesses can adopt voluntarily. For small players with limited resources and capabilities, such guidance provides a clear pathway for adoption.

5.13.2. Some organisations and government bodies created **toolkits** which assist in understanding AI's impact. For instance, AI Toolkit for c-suite executives[182] as part of World Economic Forum's Project, a practical set of tools that can help corporate executives understand AI's impact on their roles, ask the right questions, understand the key trade-offs, and make informed decisions on AI projects and implementation. Similarly, there are tools[183] to test AI maturity level of organisations, tools[184] to assess risk due to algorithms etc.

5.13.3. The assistance in the form of a collection of pragmatic approaches for adoption of AI, or in the form of toolkits to measure readiness and assess alignment with ethical principles, are the approaches to build readiness in industry and bolster adoption of AI.

5.13.4. From the above discussion, to accelerate adoption of AI in telecom, a compendium of **use cases and toolkits** may be framed. This may guide industry to adopt AI solutions to improve their services.

Issues for consultation

Q.37. **Whether there is a need to prepare and publish a compendium of guidance, toolkits and use cases related to AI and BD, to foster adoption in the telecom sector? If yes, what should be the process to prepare such a compendium and who should be**

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[181] https://www.pdpc.gov.sg/-/media/Files/PDPC/PDF-Files/Resource-for-Organisation/AI/SGAIGovUseCases.pdf

[182] https://www.weforum.org/projects/ai-board-leadership-toolkit

[183] https://www.vttresearch.com/en/news-and-ideas/new-online-tool-testing-organisations-ai-maturity

[184] https://www.canada.ca/en/government/system/digital-government/digital-government-innovations/responsible-use-ai/algorithmic-impact-assessment.html

assigned this task? Please justify your response with rationale and global best practices, if any.

5.14. Establish Centre for Excellence (CoE)

5.14.1. The risks and constraints highlighted in previous chapters hinder the adoption of AI. Various enablers and initiatives have been discussed in above sections to address these risks and constraints. However, there may exist some areas where research may help to improve the performance of the network. Thus, for this purpose, Centres of Excellence have been the key focus for many nations to ace the race to become global champions in AI. For instance, the EU Commission's report[185] recommends creation of testing and experimentation sites to support the development and subsequent deployment of novel AI applications. The Commission facilitates the creation of excellence and testing centres that can combine European, national and private investments. In parallel to the EU's approach, the following intiatives have been taken:

    i. Germany has created Competence Centres for AI Research[186];

    ii. Finland established Finnish Centre for Artificial Intelligence (FCAI)[187] to promote both AI research, and the use and application of AI, granted EUR 8.3 million in flagship funding for 2019–2022.

    iii. Denmark allocated DKK 100 million for establishing a Digital Research Centre[188] to research in AI, big data, IoT and IT Security.

    iv. The Federal Government in USA has set up AI Centre Of Excellence[189]

5.14.2. The importance of CoE has also been brought out by NITI Aayog in the

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[185] https://ec.europa.eu/info/sites/default/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf
[186] https://www.dfki.de/en/web/
[187] https://fcai.fi/
[188] https://direc.dk/artificial-intelligence-machine-learning-computer-vision-natural-language-processing-ws2/
[189] https://coe.gsa.gov/

discussion paper on National Strategy on AI (refer to Annexure II). Also, many Centres of Excellence and research labs are being set up at India's premier universities to help improve the country's research output. Many of these centres are set up in partnership with major IT organisations where both the academia and the organisations can get an edge in areas of emerging technologies. Some of the renowned CoEs for data science and AI at Indian universities are mentioned on IndiaAI portal[190].

5.14.3. CoE may focus on various aspects such as researching methods to mitigate risks from AI, finding ways to preserve user privacy, reducing skill gap and bolster adoption. CoE for AI in telecom may be established with an objective to leverage not just AI and BD but also other emerging technologies in the telecom sector. Further, the academia and startups working in the field of AI and BD may be made part of such CoE. Such Industry-academia partnership may help in advancing research and creating a skilled workforce. To begin with, the aspects of AI for adoption may also be dealt with by Telecom Centres of Excellence (TCoEs)[191] established by DoT[192] as a PPP initiative, in February 2008.

Issues for consultation

Q.38. **Whether there is a need to establish telecom industry-academia linkages specifically for AI and BD to accelerate the development and deployment of AI products and solutions? Whether there is a need to establish Centres of Excellence (CoEs) for this purpose or it can be achieved by enhancing the role of existing TCoE? Please justify your response with rationale and global best practices, if any.**

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[190] https://indiaai.gov.in/article/top-10-ai-research-centres-at-indian-universities
[191] http://www.tcoe.in/
[192] https://dot.gov.in/telecom-centres-excellence-tcoe-india

Q.39. Whether there is a need to establish telecom industry-academia linkages specifically for AI and BD for AI related skill development? Please give the suggestions for strengthening the industry-academia linkages for identification of the skill development courses. Please justify your response with rationale and global best practices, if any.

CHAPTER 6

ISSUES FOR CONSULTATION

Q.1.   What may be the most appropriate definition of Artificial Intelligence (AI)? What are the broad requirements to develop and deploy AI models in a telecom sector? Whether any major challenges are faced by the telecom service providers in adopting AI? Please justify your response with rationale and global practices, if any.

Q.2.   Whether the big data in the telecom sector may be utilised for developing AI models? For efficient and effective handling of big data, whether there is a need for adoption of special programming models or software frameworks? Please justify your response with suitable examples and global practices, if any.

Q.3.   Whether deployment of 5G and beyond technologies will help to accelerate adoption of AI in all the sectors and vice versa? Please justify your response with suitable illustrations including global practices, if any.

Q.4.   Do you think that a number of terminologies such as Trustworthy AI, Responsible AI, Explainable AI etc. have evolved to describe various aspects of AI but they overlap and do not have any standardised meanings? If yes, whether there is a need to define or harmonise these terms? Please justify your response with rationale and global practices, if any.

Q.5.   Which are the applications of AI and BD already being used by the TSPs in their networks to improve Quality of Service, Traffic Management, Spectrum Management and for Security purposes? Please list out all such applications along with the level of maturity of such applications. Please specify whether they are at trial stage or pilot stage or have reached the deployment stage? Details should include type of AI models, methods to access data, and procedures to

ensure quality of data.

Q.6.   What are the major challenges faced by the telecom industry, including policy and regulatory, in developing, deploying, and scaling applications of AI listed in the response to Q.5? How can such challenges be overcome? Please justify your response with rationale and suitable examples, if any.

Q.7.   In which areas of other sectors including broadcasting, existing and future capabilities of the telecom networks can be used to leverage AI and BD? Please justify your response with rationale and suitable examples if any.

Q.8.   Whether risks and concerns such as privacy, security, bias, unethical use of AI etc. are restricting or likely to restrict the adoption of AI? List out all such risks and concerns associated with the adoption of AI. Please justify your response with rationale and suitable examples, if any.

Q.9.   What measures are suggested to be taken to address the risks and concerns listed in response to Q.8? Which are the areas where regulatory interventions may help to address these risks and concerns? Please justify your response with rationale and suitable examples, if any.

Q.10.   What measures do you suggest to instil trust and confidence regarding a robust and safe AI system among customers, TSPs and other related entities/stakeholders? Whether adopting general principles such as Responsible AI and ethical principles at the time of designing and operationalising the AI models will help in developing ethical solutions and instilling trust and confidence in the users? What may be such principles and who should formulate these and how compliance can be ensured? Please justify your response with rationale and suitable examples, if any.

Q.11.   Whether there is a need of telecom/ICT sector specific or a common authority or a body or an institution to check and ensure

compliance of national level and sector specific requirements for AI? If yes, what should be the composition, roles and responsibilities of such authority or body or institution? Please justify your response with rationale and suitable examples or best practices, if any.

Q.12.   In response to Q.11, if yes, under which present legal framework or law such authority or body or institution can be constituted and what kind of amendments will be required in the said law? Or whether a new law to handle AI and related technologies is a better option? Please justify your response with rationale and suitable examples or best practices, if any.

Q.13.   Whether telecom/ICT industry is facing constraints such as access to data, lack of computing infrastructure, lack of standards, and R&D in the adoption of AI and BD technologies? Please list out all such constraints with adequate details.

Q.14.   What measures are required to make data and computing infrastructure available and accessible to developers and also to make data/AI models interoperable and compatible? Please respond along with examples, best practices and explanatory notes.

Q.15.   Whether there is a gap between requirement and availability of skilled AI workforce? If so, what measures are required to be taken to ensure availability of adequate skilled workforce in AI domain? Please respond along with suggestions with supporting details and best practices.

Q.16.   What initiatives do you suggest to democratise data required to develop AI models in the telecom sector? Please justify your response with rationale and suitable examples, if any.

Q.17.   Whether the authority or body or institution as suggested in response to Q.11 may also be entrusted with the task to manage and oversee collection, cataloguing and storage of data? Whether such authority or body or institution need to be entrusted to generate and make available synthetic data? Please justify your response with

rationale and suitable examples, if any.

Q.18.   Whether the legal framework as envisaged in para 3.5.3 and Q.12 should also enable and provide for digitalisation, sharing and monetisation for effective use of the data in AI without affecting privacy and security of the data? Please justify your response with rationale and suitable examples, if any.

Q.19.   (a) Which are the currently used privacy enhancing and privacy preserving technologies facilitating adoption of AI and BD? Are there any challenges in using these technologies? How these challenges can be addressed?

(b) Which are the potential technologies likely to be available in near future to further strengthen privacy?

Please justify your response with rationale and suitable examples, if any.

Q.20.   Whether the list of technologies provided in response to Q.19 are adequate to handle all the perceived risks and concerns in the AI domain? Or is there a need to develop new privacy preserving architecture? Please justify your response with rationale and suitable examples, if any.

Q.21.   Whether the next generation telecom network architectures such as AI at edge, federated learning, TinyML or their combination can offer solutions to meet both privacy as well as intelligence requirements? Please justify your response with rationale and suitable examples, if any.

Q.22.   What type of technological advancements are happening for running the AI models on the end user devices to overcome constraints in respect of processor, memory, battery etc.? Whether special tools, programming languages, and skills are required to be developed to build such AI models? Please justify your response with rationale and suitable examples, if any.

Q.23. Considering availability of new privacy preserving architectures as suggested in response to Q.19 and Q.20, what is the likelihood of emergence of new business and operational models? Whether such models will raise issues related to ownership and responsibilities? What do you suggest to address these issues? Please justify your response with rationale and suitable examples, if any.

Q.24. Whether the concept of "Operator Platform" would help in providing AI based solutions in a unified and more equitable manner? Apart from popular federated use cases of edge cloud federation, Cloud XR, Cloud Gaming, whether this concept may also be applied for public service delivery and in making public policies that are data-driven? Whether there is a need to take initiatives for developing and demonstrating advantages of concept of "Operator Platform"? If so, what steps and measures are suggested to launch such initiatives? Please justify your response with rationale and suitable examples, if any.

Q.25. Whether there is a need to create AI-specific infrastructure for the purpose of startups and enterprises in the telecom sector to develop and run AI models in an optimised manner? Whether such an infrastructure should cover various real-world scenarios such as cloud AI, edge AI and on-device AI? Please justify your response with rationale and suitable examples, if any.

Q.26. Whether the emerging trends of development of foundational AI models such as GPT-3, Gopher etc. are leading to democratisation of AI space by offering fine-tuned or derived AI models? Whether such a trend will also help in reducing costs for the AI developers? Whether similar approach will help in development of large-scale AI model for the telecom sector? Please justify your response with rationale and suitable examples, if any.

Q.27. Whether there is a need to establish experimental campuses where startups, innovators, and researchers can develop or demonstrate technological capabilities, innovative business and

operational models? Whether participation of users at the time of design and development is also required for enhancing the chances of success of products or solutions? Whether such a setup will reduce the burden on developers and enable them to focus on their core competence areas? Please justify your response with rationale and suitable examples, if any.

Q.28.   Whether experiments are required to be backed by regulatory provisions such as regulatory sandbox to protect experimenters from any violation of existing regulations? Whether participation of government entities or authorities during experimentation will help them to learn and identify changes required in the existing regulations or introducing new regulations? Please justify your response with rationale and suitable examples, if any.

Q.29.   In response to Q.27 and Q.28, whether establishing such a campus under government patronage will enable easy accessibility of public resources such as spectrum, numbering and other resources to the researchers? Whether it would be in mutual interest of established private players as well as startups, innovators and enterprises to participate in such experiments? Please justify your response with rationale and suitable examples, if any.

Q.30.   Whether active participation in the international challenge programs such as ITU AI/ML 5G challenge will help India's telecom industry in adopting AI? Whether similar programs are also required to be launched at the national level? Whether such programs will help to curate problem statements or help in enabling, creating, training and deploying AI/ML models for Indian telecom networks? What steps or measures do you suggest to encourage active participation at international level and setting up of such programs at national level? Please justify your response with rationale and suitable examples, if any.

Q.31.   Whether AI/ML developers should launch bounty programs to establish trust in the public about robustness of measures taken by

them to protect privacy in their products or solutions? Whether conduction of such programs will help companies or firms to improve their products or solutions? Whether such programs should be conducted under the supervision of the government or an institution established/assigned for this purpose? Please justify your response with rationale and suitable examples, if any.

Q.32.   Whether the telecom industry is required to adopt a Machine Learning Operations (MLOps) environment to develop, train, validate and store ML models? Whether there is also a need to establish a DataOps feature store to help MLOps for training purposes? What standardisation is required in terms of interoperability and compatibility for MLOps to function in a federated manner? Please justify your response with rationale and suitable examples, if any.

Q.33.   Whether active participation in the international bootcamp programs such as MIT Bootcamps, Design Thinking Bootcamp by Stanford University etc. will help India's telecom industry workforce to find international developers community, navigate challenges and learn from experiences of others? Whether similar programs are also required to be launched at the national level? What steps or measures do you suggest to encourage active participation at the international level and setting up of such programs at the national level? Please justify your response with rationale and suitable examples, if any.

Q.34.   Whether the courses or programs related to AI/ML currently being offered by various institutions and universities in India are adequate to meet the capacity and competence required to develop and deploy AI solutions or products in the telecom networks? If not, what additional steps or measures are suggested to fill the gap? Please justify your response with rationale and suitable examples, if any.

Q.35.   Whether establishing a system for accreditation of AI products and solutions will help buyers to purchase such solutions or products? If yes, what should be the process of accreditation and who should be authorised or assigned with the task of accrediting such products or

solutions? Please justify your response with rationale and suitable examples, if any.

Q.36.   Whether creating a framework to prepare a list of prequalified suppliers of AI products or solutions will help industry including government agencies to procure AI products or solutions? Whether there is a need to formulate a standard Code of Conduct or guidelines for AI related procurements? What should be the typical elements of such a Code of Conduct or guidelines including guidelines on trusted source and who should be tasked to formulate such a Code of Conduct or guidelines? Please justify your response with rationale and suitable examples, if any.

Q.37.   Whether there is a need to prepare and publish a compendium of guidance, toolkits and use cases related to AI and BD, to foster adoption in the telecom sector? If yes, what should be the process to prepare such a compendium and who should be assigned this task? Please justify your response with rationale and global best practices, if any.

Q.38.   Whether there is a need to establish telecom industry-academia linkages specifically for AI and BD to accelerate the development and deployment of AI products and solutions? Whether there is a need to establish Centres of Excellence (CoEs) for this purpose or it can be achieved by enhancing the role of existing TCoE? Please justify your response with rationale and global best practices, if any.

Q.39.   Whether there is a need to establish telecom industry-academia linkages specifically for AI and BD for AI related skill development? Please give the suggestions for strengthening the industry-academia linkages for identification of the skill development courses. Please justify your response with rationale and global best practices, if any.

Q.40.   Any other issue which is relevant to this subject? Please suggest with justification.

ANNEXURE I

DoT's REFERENCE TO TRAI FOR RECOMMENDATIONS

F. No.4-27/NDCP2018-NT

Government of India

Ministry of Communications

Department of Telecommunications

(Networks and Technology Wing)

Dated: 6 June, 2019

To

The Secretary,

Telecom Regulatory Authority of India,

New Delhi.

Subject: Seeking recommendations of TRAI on NDCP-2018 provision related to Leveraging Artificial Intelligence and Big Data – reg.

The National Digital Communications Policy, 2018 seeks to unlock the transformative power of digital communications networks-to achieve the goal of digital empowerment and improved well-being of the people of India; and towards this end, attempts to outline a set of goals, initiatives, strategies and intended policy outcomes.

2. In this regard, under Propel India Mission of NDCP-2018, various strategies have been laid out to accomplish the objectives, where strategy no 2.2 relates to Ensuring a holistic and harmonized approach for harnessing Emerging Technologies.

3. In order to create a road map for Artificial Intelligence(AI) - an emerging technology & its use in the Communication sector, the provision no 2.2(g) of NDCP-2018 envisages *"Leveraging Artificial Intelligence and Big Data in a synchronized and effective manner to enhance the overall quality of service, spectrum management, network security and reliability."*

4. Accordingly, TRAI is requested to provide its recommendations under section 11 (1)(a) of TRAI Act, 1997(as amended), in respect of the afore- mentioned provision no 2.2(g) of NDCP-2018.

This is issued with the approval of Secretary(T).

(Rajiv Sinha) 06/06/19

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INITIATIVES FOR ARTIFICIAL INTELLIGENCE IN INDIA- MEITY, NITI AAYOG AND DoT

Date	Ministry/ Department	Subject
February 2018	MeitY	Constituted **four committees on AI**[193] ● Committee on Platforms and Data for AI ● Committee on Leveraging AI for identifying National Mission in Key sectors ● Committee on Mapping Technological capabilities, key policy enablers required across sectors, skilling and reskilling, R&D ● Committee on Cyber Security, Safety, Legal and Ethical Issues
June 2018	NITI Aayog	**Released** a discussion paper on **National Strategy on Artificial Intelligence**[194] consists of ***four broad recommendations***: ● promotion of research; ● skilling and reskilling of the workforce; ● facilitating adoption of AI solutions; and ● the development of guidelines for 'responsible AI'
July 2019	MeitY	Published **Report Of Committee - On Platforms And Data On Artificial Intelligence**[195] ● recommends the development of an enriched National Artificial

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193 https://www.meity.gov.in/artificial-intelligence-committees-reports
194 https://niti.gov.in/writereaddata/files/document_publication/NationalStrategy-for-AI-Discussion-Paper.pdf
195 https://www.meity.gov.in/writereaddata/files/Committes_A-Report_on_Platforms.pdf

		Intelligence (AI) Resource Platform (NAIRP) of India
		● To bring together all publicly shareable data, information, tools, literature, solutions, best-practises to enable a large number of people to individually and in collaboration take up AI tasks **INDIAai: The National AI Portal of India**[196] launched in May 2020, a joint initiative of MeitY, NeGD and NASSCOM, **aims to be the trusted content powerhouse.**
July 2019	MeitY	**Report Of Committee - on Cyber Security, Safety, Legal And Ethical Issues. Report Recommendations**[197]**:** ● Develop cyber security techniques and tools, Research to identify the new types of vulnerabilities ● Organise Cybersecurity challenges ● Anonymization Infrastructure ● Sharing of Best Practises ● National Resource Centre: establish a National Resource Centre for AI in Cyber Security.
July 2019	MeitY	**Report Of Committee - On Leveraging A.I For Identifying National Missions In Key Sectors**[198] ● National missions are selected in each sector. ● For each mission, important technical tasks be identified ● Data available with ministries and departments be brought onto common platforms in well-defined formats.
July 2019	MeitY	**Report Of Committee – On Mapping Technological Capabilities, Key Policy Enablers Required Across Sectors, Skilling And Re-skilling, R&D**[199]

196 https://indiaai.gov.in/
197 https://www.meity.gov.in/writereaddata/files/Committes_D-Cyber-n-Legal-and-Ethical.pdf
198 https://www.meity.gov.in/writereaddata/files/Committes_B-Report-on-Key-Sector.pdf
199 https://www.meity.gov.in/writereaddata/files/Committes_C-Report-on_RnD.pdf

		● Make public data available for AI with clear and transparent controls ● nable, rather than constrain, usage through supportive policies and regulations ● Remove bottlenecks arising from legacy regulations that curb adoption of AI. ● Enable collaboration by encouraging POCs implemented with voluntary contribution by large technology companies and support them with Government counterpart funding

Jan 2020	NITI Aayog	**Published Approach Paper on AIRAWAT[200]** (AI Research Analytics &knoWledge Assimilation plaTform): AI Specific Cloud Computing Infrastructure
		
		● <u>Set up an AI-specific cloud infrastructure</u> to facilitate research and solution development in using high performance and high throughput AI-specific supercomputing technologies.
		● Key design considerations:
		    ○ an interdisciplinary task force: representation of both developer community and user domain experts in advisory capacity
		    ○ Structure of the facility: centralised or decentralised or utilise existing infrastructure
		    ○ Modes of access
		    ○ Architecture of facility

April 2020	NeGD, MeitY, GoI	Launched **National Program for Government Schools: Responsible AI for Youth[201]** designed to reach out to students and provide opportunity to become part of the skilled workforce
21July 2020	NITI Aayog	**Published draft discussion paper on Working Document:**

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[200] https://niti.gov.in/sites/default/files/2020-01/AIRAWAT_Approach_Paper.pdf

[201] https://responsibleaiforyouth.negd.in/about

		Responsible #AIforAll[202]. ● Principles of Responsible AI ○ Safety and Reliability, Equality, Inclusivity and Non-discrimination, Privacy and security, Transparency, Accountability, Protection and reinforcement of positive human values
Dec 2020	NITI Aayog	**Published Working Document: Enforcement Mechanisms for Responsible #AIforAll[203]** ● Under this, A flexible risk-based approach must be adopted, thus the National Strategy for Artificial Intelligence **proposes an Oversight Body.** ○ Manage and update Principles ○ Research technical, legal, policy, societal issues of AI ○ Provide clarity on responsible behaviour through design structures, standards, guidelines, etc ○ Enable access to tools and techniques ○ Coordinate with various sectoral AI regulators, identify gaps and harmonise policies across sectors
02 Sept 2020	DoT	**Report By AI Standardisation Committee, Dot on INDIAN ARTIFICIAL INTELLIGENCE STACK[204]** ***DoT had formed an AI standardisation committee to*** ● develop various interface standards ● develop the India's AI stack ○ structured across all sectors - ○ ensuring protection of data; data federation, data minimisation; open algorithm framework; defined data structures; interfaces and protocols, proper monitoring,

[202] http://niti.gov.in/sites/default/files/2020-11/Towards_Responsible_AIforAll_Part1.pdf
[203] https://niti.gov.in/sites/default/files/2020-11/Towards-Responsible-AI-Enforcement-of-Principles.pdf
[204] https://www.tec.gov.in/pdf/Whatsnew/ARTIFICIAL%20INTELLIGENCE%20-%20INDIAN%20STACK.pdf

audit and logging; data privacy; ethical standards; digital
rights; trustworthiness; etc

- ○ five main horizontal layers
  - ■ the infrastructure layer; the storage layer; the
    Compute layer; the Application layer and the Data/
    Information exchange layer and
- ○ One vertical layer –
  - ■ the Security and governance layer

About proposed AI Stack

- ● five main horizontal layers
  - ○ **infrastructure layer:**
    - ■ Ensures setting up of a common Data controller
      including multi cloud scenarios- private and public;
    - ■ Ensures federation, encryption and minimization at
      the cloud end; and
    - ■ Ensures proper monitoring and data privacy of the
      data stored.
  - ○ **storage layer:**
    - ■ Ensures that the data is properly archived and
      stored in a fashion for easy access when queried;
      and
    - ■ Ensures that the Hot Data/ Cold Data/ Warm data
      are stored in appropriate fashion to ensure fast or
      slow data access
  - ○ **Compute layer**
    - ■ Ensures proper AI & ML analytics;
    - ■ Certain template of data access and processing to
      ensure open algorithm framework is in place;
  - ○ **Application layer**
    - ■ Ensures that the Backend services are properly and
      legitimately programmed;
    - ■ Ensure proper Transaction movement;
  - ○ **Data/ Information exchange layer and**
    - ■ Provides for End Customer Interface;
    - ■ Has Consent Framework for data consent from/to

			customers;
			■ Provides various services through secure Gateway services;
			● one vertical layer –
			○ **Security and governance layer**: a cross cutting layer across all above layers that Ensures that AI services are safe, secure, privately protected, trusted and assured.
Feb 2021	NITI Aayog		**Approach Document for India Part 1 – Principles for Responsible AI**
			● Focus on **Examining the potential risks** and categorised Impact of AI systems into -
			○ **Direct impacts studied under system considerations:** Implications caused due to citizens being subject to decisions of a specific AI system. Typically result from system design choices, development and deployment practises. **Eg.** biasedness, Lack of explainability, Privacy & security risks, etc
			○ **Indirect impacts studied under societal considerations:** Implications caused due to the overall deployment of AI solutions in society. Which have potential repercussions on society beyond the stakeholder directly interacting with the system. **Eg**. Job loss, Malicious psychological profiling
			○ On the basis of Systems and Societal considerations, the Paper **identifies 7 broad principles** for responsible management of AI **:**
			■ Safety and Reliability, Equality, Inclusivity and Non-discrimination, Privacy and security, Transparency, Accountability, protection and reinforcement of positive human values.
			● **Approaches for managing AI Systems**
			○ Legal and Regulatory Approaches for Managing AI Systems
			○ Technology Based Approach for Managing AI Systems.
			○ Principles for Responsible Management of AI Systems
Aug	NITI		**Approach Document for India Part 2 – Operationalizing**

2021	Aayog	**Principles for Responsible AI**	

2021	Aayog	**Principles for Responsible AI**
		
		● Identifies a series of actions that the ecosystem must adopt to drive responsible AI. These actions are divided among three stakeholders: government, the private sector and research institutions
		● **Areas for Government intervention**
		  ○ Regulatory interventions towards creating a trusted AI ecosystem: Risk-based regulatory mechanism recommended
		  ○ Policy interventions to enable a responsible AI adoption:
		    ■ Custodian of responsible AI principles shall monitor the responsible AI environment, update the Principles and identify mechanisms to translate them to practice on an ongoing basis.
		    ■ Research into technical, legal, policy and social aspects of responsible AI in India
		    ■ Enable access to data, responsible AI tools and techniques
		    ■ Develop India's perspectives on responsible AI
		  ○ Awareness and capacity building on responsible AI in the public sector
		  ○ Facilitate alignment of procurement mechanisms with responsible AI principles
		● **Actions for the Private Sector:**
		  ○ Industry-led and collaborative workshops, conferences, Seminars
		  ○ Creation of open materials, tools and technologies
		  ○ Internal ethics boards, self-assessment guides and external audits to enforce guidelines
		  ○ Mandate responsible AI practises in Government Procurement
		● **Actions for Research and Educational Institutions**
		  ○ Development of curriculum: Foundational courses, Graduate and postgraduate programs on responsible AI
		● an **advisory body** with multi-disciplinary expertise is proposed to strengthen and advise the existing Government machinery,

| | | driving convergence across sectors and States. |
| | | A **Council for Ethics and Technology (CET)** is proposed for India. |

LIST OF ABBREVIATIONS

Sr. No.	Abbreviation	Meaning
1	4IR	Industry Revolution 4.0
2	AI	Artificial Intelligence
3	AIOps	Artificial Intelligence and operations
4	AIRAWAT	AI Research Analytics and Knowledge Assimilation Platform
5	AIWG	Working Group on AI
6	ALU	Arithmetic Logic Unit
7	ANN	Artificial Neural Networks
8	API	Application Program Interface
9	ASIC	Application-Specific Integrated Circuit
10	BARC	Broadcast Audience Research Council of India
11	BARC	Broadcast Audience Research Council of India
12	BBU	Baseband Unit
13	BD	Big Data
14	BTS	Base Transceiver Stations
15	CAGR	Compound Annual Growth Rate
16	CAPEX	Capital Expenditure
17	CDR	Call Detail Record
18	CNN	Convolutional Neural Networks
19	COE	Centre For Excellence
20	COMPASS	Correctional Offender Management Profiling For Alternative Sanctions
21	CRM	Customer Relationship Management
22	CSS	Cooperative Spectrum Sensing
23	CUDA	Compute Unified Device Architecture
24	DataOps	Data and operations
25	DDoS	Distributed Denial of Service
26	DevOps	Development and operations
27	DoT	Department of Telecommunications
28	DRG	Data Relay Gateway
29	DSM	Dynamic Spectrum Management
30	ERP	Enterprise Resource Planning
31	ETSI	European Telecommunications Standards Institute

32	FCC	Federal Communications Commission
33	FL	Federated Learning
34	GAN	Generative Adversarial Networks
35	GNN	Graph Neural Networks
36	GPU	Graphics Processing Unit
37	HDL	Hardware Design Languages
38	HLR	Home Location Register
39	HPC-AI	High Performance Computing-Artificial Intelligence
40	IAB	Integrated Access Backhaul
41	IDC	International Data Corporation
42	IMDA	Infocomm Media Development Authority
43	IoT	Internet of Things
44	IoT	Internet of Things
45	ISAGO	Implementation And Self-Assessment Guide for Organisations
46	ITU	International Telecommunication Union
47	IVRS	Interactive Voice Response System
48	KPI	Key Performance Indicators
49	MBD	Mobile Big Data
50	MeitY	Ministry of Electronics and Information Technology
51	MIMO	Multi Input Multi Output
52	ML	Machine Learning
53	MLFO	Machine learning function orchestrator
54	MLOps	Machine Learning and operations
55	MTTR	Mean time to repair
56	NAIRP	National Artificial Intelligence Resource Platform
57	NDCP	National Digital Communications Policy
58	NFV	Network Function Virtualization
59	NIST	National Institute of Science And Technology
60	NITRD	Networking And Information Technology Research and Development
61	NPD	Non-Personal Data
62	NPU	Neural Processing Unit
63	NSAI	National Strategy On AI
64	OECD	Organisation for Economic Co-operation and Development

65	OP	Operator Platform
66	PDPC	Personal Data Protection Commission
67	PII	personally identifiable information
68	PU	Primary User
69	QoE	Quality of Experience
70	QOS	Quality Of Service
71	RPA	Robotic Process Automation
72	RSC	Research Super Cluster
73	SDN	Software-Defined Networking
74	SI	Sending Information
75	SKT	Sk Telecom
76	SON	Self Organising Network
77	SQL	Structured Query Language
78	SU	Secondary Users
79	TCCCPR	Telecom Commercial Communication and Customer Preference Regulation
80	TPU	Tensor Processing Unit
81	TSP	Telecom Service Providers
82	UCC	Unsolicited Commercial Communication
83	UTM	Unregistered Telemarketers
84	VOLTE	Voice over LTE
85	WEF	World Economic Forum
86	XAI	Explainable AI
87	ZSM	Zero touch network & Service Management