# Artificial Intelligence In Communication Engineering

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# ARTIFICIAL INTELLIGENCE IN COMMUNICATION ENGINEERING

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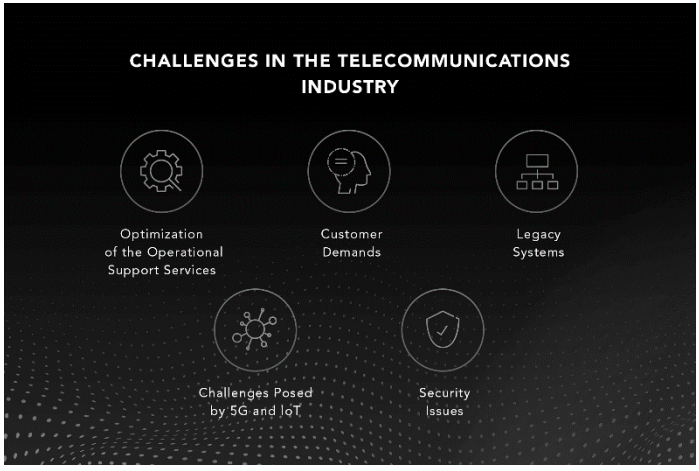
# Chapter - 1

# Challenges Of The Telecommunications Industry

The telco industry faces today a number of challenges related to growing market demands and economic pressure.

With millions of subscribers and a growing number of telco products, today's communication service providers (CSPs) have to invest a lot of effort and resources in the optimization of the operational support services.

As the telecommunications sector expands its networks at a rapid pace, service configuration, customer care, and billing processing become more complex. Facing increasing customer demands for higher quality services, CSPs continually seek useful innovations and applications to provide their customers with better customer experience and service.



Another major challenge for the telco industry is the advance of the newest wireless networks such as 5G (the fifth generation of wireless networks) and IoT (Internet of Things) which lead to a massive generation of vast amounts of data. To efficiently manage these data, CSPs are facing an increasing need for data-driven solutions.

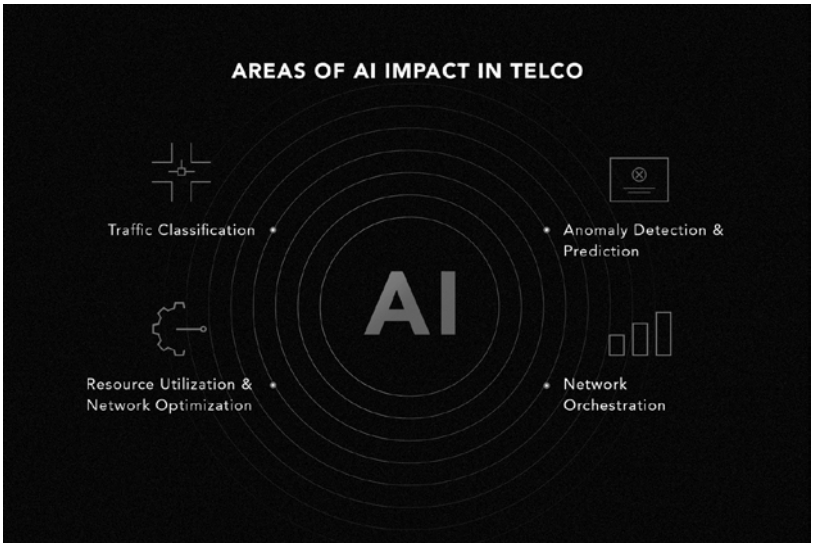
As a result of the rapid growth of IoT, a lot of new devices emerge on the market, which on one hand contributes to the market growth, while on the other hand brings new challenges in terms of security. As many IoT devices are at risk for malware-carrying applications, fraud prevention has now become the main priority for the telecommunications industry. In order to protect personal data collected from IoT devices, telco providers need to consider opportunities that emerging technologies are offering.

## 1.1 AI's Role in the Telecommunications

The key driver for AI growth in the telco industry is an increasing demand for autonomously driven network solutions. The networks of the telecommunications industry expand at a rapid pace, becoming more complex and difficult to manage. By using AI-powered network solutions, CSPs can reduce network congestions and improve network quality, therefore enhancing the customer experience.

Market Research Future predicts that, by 2023, global AI in the telecommunication market will reach $1 billion, with 32% CARG during 2018-2023.

"AI is expected to have an impact in a multitude of areas – the most important being traffic classification, anomaly detection and prediction, resource utilization and network optimization, along with network orchestration. Further, it will also assist the mobile devices with virtual assistants and bots."




Being an umbrella term, AI can be divided into different technology segments, such as machine learning, deep learning, natural language processing, image processing, and speech recognition. However, a central role in the telecommunications industry belongs to machine learning, deep learning, and natural language processing.

## 1.2 What Types of AI Will Help Telco?

### Machine Learning

Machine learning (ML) is a subset of AI, which focuses on a computer program that is able to parse data using specific algorithms. Such a program is able to modify itself without human intervention, producing the desired output based on analyzed data. In essence, using ML techniques, a machine is trained to analyze huge amounts of data and then learn to perform specific tasks.

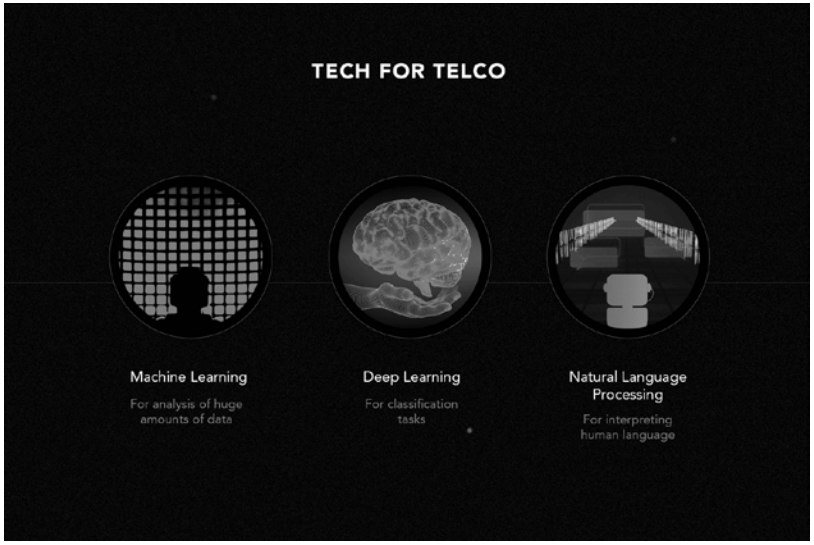
### Deep Learning

Deep Learning (DL) is a subset of machine learning, whose algorithms and techniques are similar to machine learning, but capabilities are not analogous. The main difference between ML and DL lies in the interpretation of the data they feed on. In DL, a computer system is trained to perform classification tasks directly from sounds, texts, or

images by using a large amount of labeled data, as well as neural network architectures.

## Natural Language Processing

Natural Language Processing (NLP) is a sub-field of AI, which is focused on enabling computers to understand, interpret, and manipulate human language. In essence, NLP allows machines to read texts, hear sounds, interpret them, and measure sentiments.




***AI Applications in the Telco Industry***

## Network optimization

With self-optimizing networks (SONs) powered by AI, telco providers can automatically improve network quality and as a result, provide better quality services to their subscribers. By using advanced algorithms, AI systems can process large amounts of data, in particular call detail records (CDR), in the case of the telecommunication industry, identify patterns, detect and predict network anomalies.

## Virtual assistants

According to a report by ABI Research, by 2022 virtual assistants will enable telecom service providers to save $1.2 billion on customer care

management, resulting in a compound annual growth rate (CAGR) of 17% over the next five years.

Intelligent Virtual Agents based on AI technologies gain traction in the telecommunication sector, resulting in improved customer experience and satisfaction. Telecom providers have turned to virtual assistance in order to optimize the processing of the huge number of support requests for troubleshooting, billing inquiries, maintenance, device settings, etc. AI-powered assistants handle all service-type questions and process transactions efficiently and at high speed.

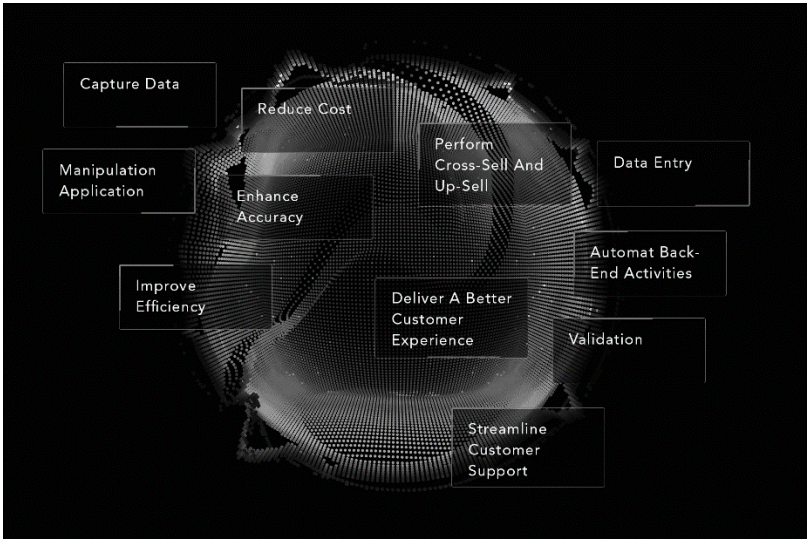
### Robotic Process Automation (RPA)

Robotic Process Automation is a technology that configures computer software to capture data and manipulate applications in the way it is done by humans. With RPA telco providers can automate back-end activities such as data entry, reconciliation, or validation, streamline customer support as well as perform cross-sell and up-sell by means of AI-powered assisted calls. RPA applications allow CSPs to reduce costs, enhance accuracy, improve efficiency and deliver a better customer experience.

## 1.3 Modernization of Telco Legacy Systems

Legacy systems are outdated applications that can no longer keep up their objectives and run effectively. As we discussed in our previous article, constant support of legacy systems costs companies huge efforts and high amounts of money.

According to Dell, during the last 10 years, a significant number of all applications used by Fortune 5000 companies “run in legacy environments built 20, 30, even 40 years ago». Moreover, Dell states «a typical corporation spends between 60 and 80 percent of its IT budget simply to maintain existing mainframe systems and applications». Replacing outdated inefficient systems with more effective AI-based applications will help telecommunications companies optimize workflow and maximize profit.




***AI Business Cases in the Telecommunications Industry***

## Telia

Telia Company AB is the fifth largest telecom operator in Europe with more than 20,000 employees and over 23 million subscribers. It is present in Sweden, Finland, Norway, Denmark, Lithuania, Latvia, and Estonia. Applying AI and ML-powered technologies, Telia can identify the most valuable accounts based on available data, keeping the company's database always up-to-date. Furthermore, the company has added virtual assistants to its customer services and claims in a case study that within a first month one of the chatbots has saved it €1 million.

## China Mobile

The world's largest mobile provider with over 902 million subscribers, China Mobile Communications Corp, is leveraging AI-embedded and big data technologies for fraud detection. The company has introduced a new product – a big data-based anti-fraud system, called Tiandun- which is able to detect fraudulent activity, distinguish it from normal calls and intercept spam texts or calls.

## Vodafone

Vodafone Group is a British multinational telecommunications conglomerate with more than 500 million customers. The company has improved customers services with the arrival of its virtual assistant app TOBi. Tobi is able to enhance customers' engagement and personalize the sales journey. Being a text bot, TOBi can directly answer most customer questions, address problems, or suggest and offer more suitable products.

The use of AI/ML in the dynamic instantiation of network slicing and the end-to-end orchestration of network domains is key to driving 5G network automation. It enables operators to deliver new and innovative services, including 5G Network-as-a-Service (NaaS). While there are major advancements in AI/ML-based network automation, challenges abound in deploying this network-wide, and in translating it, effectively, into new revenue streams across various 5G use cases.

## Operators' network slicing application strategy

Although network slicing has been among the hot topics of discussion in the communications industry in terms of the 5G technology rollout, there is definitely a visible discrepany in what operators understand by the network slicing idea.

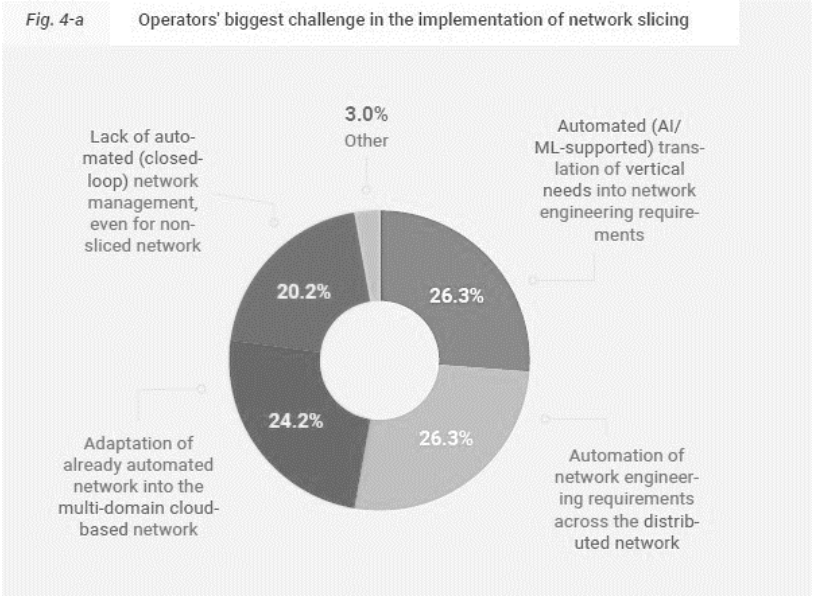
Turns out, the majority of survey respondents perceive network slicing as a smart mechanism that will allow customers to rent highly customized and virtualized pieces of the network on on-demand basis. Another big part of the operators believe network slicing to be best implemented in three slices that correspond to the 5G service categories: eMBB, URLLC and mMTC. A small percentage of CSPs thinks that the technology will have appliance in only one category – URLLC, or mMTC. Only one percent of the respondents do not find network slicing to be of value in the nearest future.

## Network slicing as the first step towards NaaS and 5G monetization

The conducted research shows that even close to 95% of the responders expect NaaS to have a major impact in driving operator revenues, and almost one third of those believe that it will be a real game changer. It's

hard not to agree – Network-as-a-Service will allow operators to deploy new services even quicker, and in an even more digitalized way. NaaS therefore offers a way to have more services, gain new customers, but also create new possibilities for partnerships.

Nevertheless, in order to start up with NaaS, operators first need to deal with some challenges that network slicing brings – and among those automation seems to be the biggest.




## Telco operating models, NaaS monetization partnerships, and more

Uncover the whole report, produced jointly by Comarch and The Fast Mode, and read the findings in such areas as 5G network slicing application and vertical slicing models, the role of AI/ML in 5G network automation, the adoption of virtualization and edge computing, the impact of IT-telco convergence on operator operating models, 5G NaaS solution models and monetization partnership opportunities.

AI-embedded technologies can be a useful tool in the telecommunications industry. Implementation of AI by telco companies resulting in the development of highly personalized products, improved fulfillment processes, and enhanced network management, allows

telecommunications operators to provide their customers with more attractive services as well as improve their customer retention.

# Chapter - 2

# Artificial Intelligence In 5g Telecom

The times when the use of artificial intelligence in network operations was proof of thrift are passing. We are entering a new era, where the intensification of activities in the provisioning and maintenance of telecommunications services will force companies to utilize more AI-driven modern tools to support operations and fulfill customers' needs.

We believe that the "miracle of SMS" will repeat itself. SMS was designed as a niche -not a very attractive service to the end customer. At least, that's what was thought. In reality, the service has conquered the world. Its career did not last long, as it was replaced by more innovative, universal methods of communication, but the phenomenon of popularity that was exceeding the wildest predictions of its creators remained.

The constructors of 5G networks promise us some possibilities, but a lot depends on how the networks are developed by the service providers. This also relies on one simple thing – customer pressure to receive the services that they dream about.

Today we already have many successful implementations of 5G networks. But did things really change that much? Unfortunately – no. In order to make a change, operators have to, well, make a change – specifically in their network architecture. Right now, most mobile network access elements that are implemented allow the use of services as they have been so far, only with greater efficiency possibilities. None of the CSPs have yet developed such changes that would allow the rollout of new 5G telecommunications services.

Therefore, the time of artificial intelligence in the provision and maintenance of telecommunications services is yet to come. Only when the entire network fulfills the promises of the constructors, on the basis of which service providers will construct services, will there be a

significant change. We will be dealing with another revolution in mobile communications, such as the transition from analog to digital systems. Based on these experiences, it is virtually impossible to predict the magnitude of these changes. But it is sure that it will be a real break from today’s norm.

From the tiny, closed systems provided by hardware manufacturers, eagerly guarding the monopoly on the management of their own equipment, a digital world of open interfaces and digital management has emerged, and the race to provide ever higher quality has started.

The principle that a service management tool must be at least as technologically advanced as the service itself (or rather, as the infrastructure that provides it) will still be relevant and probably even more important in the race to attract customers. Why? There will be no time to "get the system up and running". Unlike in the past, customers will strike in great numbers all at once. They will be hungry for new products, and there is no point in dreaming that prices can try to suppress these appetites.

Changes in the provision and maintenance of telecommunications services are quickly approaching. The highly competitive market will force the search for relatively cheap systems ensuring changes in services in a very short time. Suppliers and system users must be prepared for these updates. There are many actions that will be necessary, and which can be taken today. There’s no more time to waste.

On the market of artificial intelligence solutions and techniques, there will be equally intense competition for customers, who will in this case be telecommunications service providers. Several different solutions are already available, employing a very wide range of approaches to the subject, but because there’s a lack of real services based on the promises of 5G technology developers, it is still only a theoretical attempt to compare their advantages and disadvantages. However, when these services appear, there will be a very little time for detailed analysis and decisions.

Therefore, while today's decisions carry some risk, failing to take them will guarantee that system shortfalls will hamper the delivery and

maintenance of services, damaging sales prospects in the most lucrative period. As always, there will be big winners and losers.

## 5G Telecom Standards:

An experienced CTO may claim they know best, and there's a chance they might be right – this is how we explore new ground. But in reality, the chances of this CTO being successful with a different approach than that defined by a panel of experts at SDO are rather slim.

These days, we are bombarded from all directions with new reference architectures, API specifications, best workflows and recommendations. It can be difficult to know what's spam, and what really matters.

We have reached our level of civilization mainly through knowledge sharing and learning from mistakes, whether our own or those made by others. A standard published by an experienced body is a combination of both. We gain access to recommendations from field experts who have already explored previously uncharted territories. They also learned hard lessons by doing things differently for us.

With 5G emerging all around the world, we can notice another trend – reworking software stacks. The process of standardization goes hand in hand with this. When a telecom decides to simplify the IT side of its business, the first question is about compliance with standards. If a solution supporting globally recognizable standards is selected and incorporated into the legacy landscape, it is a step in the right direction for the entire IT department. The resulting exchange or expansion of software allows smooth integration over standardized API, instead of time and cost-consuming analysis and development of two legacy APIs.

This approach allows the composition of telecom software in a manner similar to Lego® blocks, where each block is compatible with the others, and all you need to do is connect them

In the context of 5G, we need to talk about orchestration, automation, zero-touch provisioning and maintenance. How can you do this if your network consists of more than 10 different vendors and includes all the exotic technologies available?

Imagine if your vendors comply with the standard at the level of API you are integrating with their systems. You do not need to concern yourself with vendor-specific data modelling or different ways of managing objects. All the complexity is hidden under the standard API. All you have to do is ask your vendor for the standards-based API. The path here it not an easy one, though. In most cases, it means an investment on the supplier side, which they're most likely not keen to make. Standardization of API is also a risk for the vendor (which is not a secret). If APIs are standards-based, then replacing the vendor is much easier and cheaper. But, from the telecom perspective, the advantages are obvious - let the best win

## 2.1 The Role of Maintenance in Deploying and Monetizing 5G Networks:

With the widespread introduction of 5G services imminent, communication and digital service providers need to face some difficult challenges. The biggest one seems to be automation, which is crucial for deploying and, even more importantly, successfully managing and maintaining 5G networks.

The pressing need for telecoms to automate their processes inspired us to come up with a solution that is not only efficient, but also time and cost effective for CSPs/DSPs.

The accelerating pace of the popularity of remote activities creates an urgent need in terms of delivering high quality and fast Internet service for customers. Communication and digital service providers must meet consumer requirements or deal with the consequences, which in the long-run mean losing more and more customers to the competition.

Yet, this growing demand for 5G services and applications can be met, and doing so is easier than one may think

Let's start by defining one of the biggest problems that emerged alongside consumer demand for faster and more reliable connection: maintenance.

In order for businesses and consumers to utilize 5G services such as autonomous cars, remote surgeries or VR/AR enhanced events, the

connection needs to be 100% reliable. To achieve this, operators need to monitor the network 24/7 and detect any potential issues before they happen and disturb the end-users.

Humans cannot control such vast and complex connections sufficiently in terms of 5G networks. That's why introducing an AI/ML-based solution is a must.

To fulfill the promise of 5G networks and 5G services, we need fully automated predictive, preventive and corrective maintenance. All these stages – monitoring, preservation, and corrective actions are crucial to the accurate functioning of the physical and virtual infrastructure.

Introducing AI in all of those fields sounds complicated and expensive, yet this does not have to be the case if we approach the subject in the right way

Instead of focusing on technological improvements, we can use what we already have in a more sophisticated way. This means that communication and digital service providers can achieve their goals without having to spend a vast amount of money and time on new solutions for automation.

Today's communications service providers (CSPs) face increasing demands for higher quality services and better customer experience (CX). Telcos are capitalizing on these opportunities by leveraging the vast amounts of data collected over the years from their massive customer bases. This data is culled from a range of channels, such as:

- Devices
- Networks
- Mobile applications
- Geolocation
- Detailed customer profiles
- Service usage, and
- Billing data.

Telcos are also harnessing the power of AI to process and analyze these huge volumes of big data. Utilizing AI in telecom companies, allows them to extract actionable insights and provide better customer experience, improve operations, and increase revenue through new products and services.

**Forward-thinking CSPs have focused their AI investments on four main areas:**

1. Network optimization
2. Preventive maintenance
3. Virtual Assistants
4. Robotic process automation (RPA)

In these areas, AI has already begun to deliver tangible business results.

## 2.2 AI for Network Optimization in 5G:

AI is essential for helping CSPs build self-optimizing networks (SONs). These give operators the ability to automatically optimize network quality based on traffic information by region and time zone. AI in the telecom industry uses advanced algorithms to look for patterns within the data, enabling telcos to both detect and predict network anomalies. As a result of using AI in telecom, CSPs can proactively fix problems before customers are negatively impacted.

The number of operators investing in AI systems to improve their infrastructure is expected to grow to 70% in 2025. Some popular telecom AI use cases include:

- ZeroStack's ZBrain Cloud Management, which analyzes private cloud telemetry storage and use for improved capacity planning, upgrades and general management
- Aria Networks, an AI-based network optimization solution that counts a growing number of Tier 1 telecom companies as customers
- Sedona Systems' NetFusion, which optimizes the routing of traffic and speed delivery of 5G-enabled services like AR/ VR

- Nokia launched its own machine learning-based AVA platform, a cloud-based network management solution to better manage capacity planning. It also predicts service degradations on cell sites up to seven days in advance.

## 2.3 AI for Predictive Maintenance:

AI-driven predictive analytics are helping telcos provide better services by utilizing data, sophisticated algorithms and machine learning techniques to predict future results based on historical data. This means operators can use data-driven insights to monitor the state of equipment and anticipate failure based on patterns. Implementing AI in telecoms also allows CSPs to proactively fix problems with communications hardware, such as:

- Cell towers
- Power lines
- Data center servers, and even
- Set-top boxes in customers' homes.

In the short term, network automation and intelligence will enable better root cause analysis and prediction of issues. Long term, these technologies will underpin more strategic goals, such as creating new customer experiences and dealing efficiently with emerging business needs.

An innovative telecom AI use case is AT & T, who are using AI to support their maintenance procedures. The company has successfully employed a drone to expand its LTE network coverage during natural disasters. Additional benefits of AI in telecom include the capacity to analyze video data captured by drones for tech support and maintenance of its cell towers.

Preventive maintenance is effective not only on the network side, but also on the customer's side. Dutch telco KPN analyzes the notes produced by its contact center agents, and uses the insights generated by implementing AI in telecom to make changes to its interactive voice response (IVR) system.

KPN also tracks and analyzes customers' at-home behavior, with their permission, such as switching channels on their modem, which may signify a Wi-Fi issue. Once identified, KPN proactively follows up on these problems, driving greater successes for technical teams.

## 2.4 Virtual Assistants for Customer Support:

Another application of AI in telecom is conversational AI platforms. Also known as virtual assistants, they have learned to automate and scale one-on-one conversations so efficiently that they are projected to cut business expenses by $8 billion annually in 2022, according to Juniper Research.

AI adoption in telecom helps to contend with the massive number of support requests for installation, set up, troubleshooting and maintenance, which often overwhelm customer service centers. Using AI, operators can implement self-service capabilities that show customers how to install and operate their own devices.

Vodafone implemented TechSee's AI in telecom technology and saw a 68% improvement in customer satisfaction. They introduced their new chatbot TOBi to handle a range of customer service questions. The chatbot scales responses to simple customer queries, delivering the speed that subscribers demand.

Nokia's virtual assistant MIKA suggests solutions to network issues, leading to a 20% to 40% improvement to its first-time resolution rate.

Voice assistants, such as Telefónica's Aura, are designed to reduce customer service costs generated by phone enquiries. Comcast has also introduced a voice remote that allows customers to interact with their Comcast system through natural speech.

Further examples of AI in the telecom market include DISH Network's partnership with Amazon's Alexa. This allows customers to search or buy media content by spoken word rather than remote control. Integrating visual support within IVR enables more time-efficient interactions, reducing average handling times (AHT) and customer hold times, and ultimately driving better CX.

Want to take it further? Check out these five strategies for improving CX for telecoms customers.

## 2.5 Robotic Process Automation (RPA) for Telecoms

CSPs have vast numbers of customers engaged in millions of daily transactions, each susceptible to human error.

Robotic Process Automation (RPA) is a form of business process automation technology based on AI. RPA can bring greater efficiency to telecommunications functions by allowing telcos to more easily manage their back office operations and large volumes of repetitive and rules-based actions. RPA frees up CSP staff for higher value-add work by streamlining the execution of complex, labor-intensive and time-consuming processes, such as:

- Billing
- Data entry
- Workforce management, and
- Order fulfillment.

According to Statista, the RPA market is forecast to grow to 13 billion USD by 2030, with RPA achieving almost universal adoption within the next 5 years. Telecom, media and tech companies expect cognitive computing to “substantially transform” their companies within the next few years.

Celaton helps telecoms streamline inbound data, such as emails, web forms and posts. It uses RPA technology to extract and validate key data from each correspondence, and presents suggested responses to service reps, who then amend messages before responding to customers. Kryon, meanwhile, assists operators with identifying key processes to automate in support of both digital and human workforces for optimal efficiency.

## 2.6 The Future of AI in the Telecom Industry

AI in the telecom market is increasingly helping CSPs manage, optimize and maintain not only infrastructure, but also customer support operations. Network optimization, predictive maintenance, virtual

assistants and RPA are all examples of telecom AI use cases where the technology has helped deliver enhanced CX and added value for enterprises.

As big data tools and applications become more available and sophisticated, the future of AI in the telecom industry will continue to develop. Employing AI in telecom companies can be expected to continue accelerating growth in this highly competitive space.

View TechSee's fun infographic to learn how AI in the telecom sector, amongst others, has reduced costs by $68 billion.

# Chapter - 3

# Trends In Communication Networks And Services

Artificial Intelligence with learning abilities is a revolutionary technology, which the communication industry is exploring, with the aim of introducing it into communication networks to provide new services, to improve network efficiency and user experience. Communication is a sector with heavy ICT use, dealing with a variety of consumer demands on individualization requirements, multimedia services and precision management. Current major trends in communication networks and services are described below: -

## 3.1 Characterized requirements:

With the increasing number of users and the expanding size of the communication networks and services, habits, preferences differences and the information needs of individual users and enterprises are gradually exposed. The customized networks and services now being provided for enterprise users, which makes the demand for specialized businesses stronger. In near future special service package for each user, and even a special network may be prioritizing. Such complex requirements would be unimaginable without an intellectual tool, such as AI. 5

## 3.2 Multimedia services

Internet users, now have also become information producers, as well as information consumers, and are producing more and more information in multimedia. User-generated content increases Internet traffic exponentially. Under these circumstances, both storage and transmission

of data/ information are a great challenge. The inclusion of AI can bolsters the abilities to handle these challenges.

## 3.3 Precision management

The use of smartphones makes it inevitable that the various dimensions and granularities in today's wireless traffic system should be considered in the networks. With the development of the technologies of network function virtualization (NFV) and software-defined networks (SDN), the management of the network has become more precise. Virtualization is not only at the level of network elements, but also at the level of components such as the CPU, memory, port, bandwidth, etc. AI-based technologies allow operators to set up such on-demand networks for special users.

## 3.4 Predictable future

The increasing numbers of users and expansion of business requirements has meant that the gap between the peaks and troughs of network usage is becoming greater. In this case, operators are required to predict the future status of networks more accurately to satisfy users' demand and improve their experience. AI-driven predictive analytics are helping telecoms provide better services by utilizing data, sophisticated algorithms and machine learning techniques to predict future results based on historical data.

## 3.5 Intellectualization

Networks are becoming more heterogeneous as users often uses a variety of equipment with different wireless access technologies such as 2G, 3G, 4G, and Wi-Fi. Adoption of 5G will further reshape telecommunication networks in the near future. The network management becoming more difficult to maintain with an acceptable quality of service (QoS) due to the increase in network equipment and user terminals, the expansion of network size, the increase in the number of users, and the increasing complexity of the network. As well as expanding capacity by introducing more equipment, the operators are expected to raise their network performance with smart tools and intelligence technologies. This includes introducing more intelligence into networks and management to

meet customer needs, make more profits, reduce operating costs, and improve network performance.

## 3.6 More attention to security and safety

As AI develops, security and security will be significant factors for everyone involved in these technologies. Security incidents are growing and becoming more severe. These events have resulted in significant commercial consequences, including broken networks, economic losses, etc. AI can be used to establish strong security protection and behavioral analysis based on machine learning, will significantly improve the ability of network detection attacks, automatic analysis of data, and the identification of relationships between isolated behaviors.

## 3.7 Trends of mobile network

Today, the application of virtualized network functions (NFV) to mobile core networks is in progress. For years, various network functions, such as the conventional Evolved Packet Core (EPC), have been provided in their dedicated hardware (HW) such as Advanced Telecom Computing Architecture (ATCA) hardware. With the introduction of NFV, software will be able to run on a virtualized operating system (OS) of generic Intel architecture (IA) servers and be provided separately from hardware. Furthermore, the NFV architecture enables integrated management and control (orchestration) of network services and resources, interworking with Management and Orchestration. The application of AI will enable to respond to the above-mentioned problems in the planning and maintenance processes quickly and efficiently.

## 3.8 Big data for development and ICT monitoring

Big Data and AI are set of two amazing modern technologies that empower machine learning, continuously reiterate and update the data banks, and taking the help of human intervention and recursive experiments for the same. Data combined with steady advances in the power of computing are leading to the emergence of data-driven innovation: online activity and networked things generate “big data” which feed machine learning that enables AI, which in turn leads to advances in intelligent machines (robotics, automated vehicles) as well

as new techniques in science which can spur further innovation. The growth of the volume, variety and velocity of data and the ability to analyze and use it is a significant departure from the past and marks the emergence of a new factor of production that augments traditional capital and labor, but with unique properties of its own.

One of the richest sources of big data is the data captured by the use of ICTs. This broadly includes data captured directly by telecommunication operators as well as by Internet companies and by content providers such as Google, Facebook, Twitter, etc. Big data from the ICT services industry are already helping to produce large-scale development insights of relevance to public policy. Collectively, they can provide rich and potentially real-time insights 7 to a host of policy domains. In some countries and regions, the use of big data, including big data from the ICT industry, is subject to national regulation

# Chapter - 4

# Artificial Intelligence: Progress & Possible Uses In Communications

Innovative telecom operators use AI and machine learning to increase network reliability, improve customer satisfaction & retention, optimize their business processes for higher profit, and much more. The most visible use case for AI in telecoms is enhanced customer service. Other than customer service, telecoms use artificial intelligence in network maintenance. Top AI use cases are shown in Figure 1.

SDN, NFV, network slicing and other technologies, coupled with integrated network management systems have been able to directly issue orders which can be executed by network equipment, and DPI systems can be deployed on network equipment, and it is possible to realize real-time monitoring of networks and services and intelligent management.

## 4.1 AI in SDN

Software defined networking (SDN) represents a promising networking architecture that combines central management and network programmability. SDN separates the control plane 9 from the data plane and moves the network management to a central point, called the controller that can be programmed and used as the brain of the network, which greatly promote the capabilities of network-automated management and control. A typical SDN framework is composed of three layers: infrastructure layer, control layer and application layer. The infrastructure layer includes some network elements which can provide network traffic, acting as the object controlled by the SDN controller, as well as a data source of the network resource. The control layer has the SDN controller, which is the core component of the SDN network carrying out important tasks of controlling network traffic. The

application layer includes various applications. The southbound interface D-CPI (Data-Controller Plane Interface) is responsible for exchanging data between the SDN controller and the network element. The northbound interface A-CPI (Application-Controller Plane Interface) is responsible for providing the upper-level application with the channel exchange to obtain the underlying network resource information and send data to the lower-level network. SDN provides a good interface with its programmability to introduce AI into the communication networks. This is SDN's biggest advantage. SDN uses the application-programming interface to send powerful programming instructions to the network device.

With AI, network managers can not only schedule an automated intelligent business orchestrator, but also program the AI-optimized network strategy and automatically compile them into the task script, then assign them into the network allocation tasks with the application-programming interface (API). Network managers can also automatically collect network statistics information to lay a solid foundation for continuous network optimization. If necessary, some new functionalities can also be added intelligently through the SDN application for the network environment.

## 4.2 AI in NFV

With virtualization technology, Network Functions Virtualization (NFV) can divide network-level functions and applications, such as routing, customer premises equipment (CPE), mobile core, IP Multimedia Subsystems (IMS), content delivery networks (CDN), switching elements, mobile network nodes, home routing operations, set-top box business, tunnel gateway elements, traffic analysis, service assurance, service level agreement (SLA) monitoring, testing and diagnosis, next generation network (NGN) signal, aggregation and network range functions, application optimization, security policy, etc., into several functional blocks, and run them in software mode respectively. This means that they are no longer limited to the hardware architecture.

The typical NFV reference architecture includes three layers of the complete infrastructure layer, the resource management layer, and the business flow orchestrator layer. NFV helps ISV and telecommunication

operators to achieve virtual network functions by deploying hypervisor at the infrastructure layer to virtualize infrastructure resources such as commercial general computing, storage and network resources and others. The resource management layer is in charge of the NFV infrastructure's management, configuration and collaboration. The business flow orchestrator layer is a key part of the NFV network function for network operating; it is used to organize and orchestrate the functions of the NFV network. It is also in charge of managing and monitoring the global resources across the data center or the resource pool.

With the virtualization of network functions NFV can realize an on-demand dynamic network configuration separated from the underlying architecture. As key issues have been solved, AI can play its full role in critical network management.

## 4.3 AI and Network monitoring, security and reliability:

To master the real-time information of the communication network, the network must have the function of initiative uploading. Currently there are many DPI systems. With inspectors, the deep packet inspection (DPI) system can collect the information such as the running state of network equipment, the usage of resources and the quality of services. With the big data obtained from the DPI system, the AI system can rapidly analyse and find if there are or will be abnormity within the information. For example, if the AI system finds a burst a continuous traffic, it can doubt a distributed denial of service (DDoS) attack in the network and analyse the package characteristics immediately, then orchestrate an inspector collaboration task to drop all packages with the characteristics to avoid the damage. It could write a new record in the security database in case of the appearance of unknown hack attacks or new virus flooding.

While developing AI systems, attention must be paid to the potential security risks; strengthen prevention mechanisms and constraint conditions; minimize risks; and ensure AI's secure, reliable, and controllable development. When applying AI models, it needs to analyze and determine the risks in using AI technology based on the characteristics and architecture of specific services, and design a robust AI security architecture and deployment solution using security mechanisms involving isolation, detection, failsafe, and redundancy (Figure 2).

By detecting unusual network activity at every level of the network, an AI-enabled platform can accurately detect existing and day-zero threats. In addition, location technology can be used to accurately locate accidental or malicious rogue devices and provide location-based access to resources.

### i) Isolation:

To ensure stable operation, an AI system analyzes and identifies the optimal solution and sends it to the control system for verification and implementation. Generally, the security architecture must isolate functional modules and setup access control mechanisms between modules. The isolation of AI models can reduce the attack surface for AI inference, while the isolation of the integrated decision module can reduce attacks on the decision module. The output of AI inference can be imported into the integrated decision module as an auxiliary decision-making suggestion, and only authorized suggestions can enter the decision module.

### ii) Detection:

Adopting continuous monitoring and with an attack-detection model in the main system architecture, it is possible to comprehensively analyze the network security status and estimate the current risk level. When the risk is high, the integrated decision system can reject the suggestion coming from the automatic system and hand over control to a person to ensure security under attacks.

### iii) Failsafe:

When a system needs to conduct critical operations such as AI-assisted autonomous driving or medical surgery, a multi-level security architecture is required to ensure the entire system security. The certainty of the inference results provided by the AI system must be analyzed. When the certainty of the result is lower than a certain threshold, the system falls back to conventional rule-based technologies or manual processing.

### iv) Redundancy:

Many business decisions and data are associated with each other. A feasible method to ensure the security of AI models is to analyze whether the association has been ruined. A multi-model architecture can be set up for critical applications, so that a mistake in one model does not keep the system from reaching a valid decision. In addition, the multi-model architecture can largely reduce the possibility of the system being fully compromised by a single attack, thereby improving the robustness of the entire system.

## 4.4 AI and QoS:

The AI module consists of two different parts. The first one is a classifying part, which detects the type of traffic that is sent through the network. The second part is an estimator that informs the SDN controller on which kind of action should be executed to guarantee the Quality of Service (QoS) and Quality of Experience (QoE). Results show that with the actions performed by the network, problems like jitter and losses can be reduced.

## 4.5 ITU Work/ Focus Group on Machine Learning 5G:

ITU-T under its Study Group 13 has established a Focus Group on Machine Learning for Future Networks including 5G, to draft technical reports and specifications for machine learning (ML) for future networks, including interfaces, network architectures, protocols, algorithms and data formats. The major objectives of FG-ML5G includes:

To help adoption of ML in future networks including architecture, interfaces, use cases, protocols, algorithms, data formats, interoperability, performance, evaluation, security and protection of personal information;

To study, review and survey existing technologies, platforms, guidelines and standards for ML in future networks;

To establish liaisons and relationships with other organizations which could contribute to the standardization activities for ML.

The key lies in leveraging the right opportunities in AI.

### (i) Provability:

Organizations involved in AI cannot demonstrate clearly, why it does and what it does. No wonder AI is a "black box" as of now. People are skeptical about it, as they fail to understand how it makes decisions. Provability – the level of mathematical certainty behind AI predictions – remains a grey area for organizations. There is no way they can prove or guarantee that the reasoning behind the AI system's decision-making is clear. The solution lies in making AI explainable, provable, and transparent. Organizations must embrace Explainable AI as a best practice.

### (ii) Data privacy and security:

As AI develops, Privacy and security will be significant factors for everyone involved in these technologies. Most AI applications rely on huge volumes of data to learn and make intelligent decisions. Machine Learning systems use/ depend heavily on data, often sensitive and personal in nature, to learn from them and enhance themselves. This makes it vulnerable to serious issues like data breach and identity theft. Besides, an emerging method – 'Federated Learning', which is a machine learning setting where the goal is to train a high-quality centralized model with training data distributed over a large number of clients each with unreliable and relatively slow network connections– is all set to disrupt the AI paradigm. It will empower data scientists to develop AI without compromising users' data security and confidentiality.

### (iii) Algorithm bias

An inherent problem with AI systems is that they are only as good – or as bad – as the data they are trained on. Bad data is often laced with racial, gender, communal or ethnic biases. Proprietary algorithms are used to determine who is called for a job interview, who has granted bail, or whose loan is sanctioned. If the bias lurking in the algorithms that make vital decisions goes unrecognized, it could lead to unethical and unfair consequences. For instance, Google Photos service uses AI to identify people, objects and scenes. However, there is a risk of it displaying wrong results, such as when a camera missed the mark on

racial sensitivity, or when a software used to predict future criminals showed bias against black people.

In the future, such biases will probably be more accentuated, as many AI systems will continue to be trained using bad data. Hence, the need of the hour is to train these systems with unbiased data and develop algorithms that can be easily explained.

### (iv) Data scarcity

It is true that organisations have access to more data today than ever before. However, datasets that are relevant for AI applications to learn are indeed rare. The most powerful AI machines are the ones that are trained on supervised learning. This training requires labeled data – data that is organised to make it ingestible for machines to learn. Labeled data is limited. In the not-so-distant future, the automated creation of increasingly complex algorithms, largely driven by deep learning, will only aggravate the problem. There is a ray of hope though. As a trend that is fast catching up, organisations are investing in design methodologies, trying to figure out how to make AI models learn despite the scarcity of labeled data. 'Transfer learning', 'Unsupervised/Semi-Supervised Learning', 'Active Learning', and so on are just a few examples of the next-generation AI algorithms that can help resolve this.

Artificial Intelligence is seen as a great transformative tech and the possibilities seem almost limitless to what it can eventually do. With these disruptive developments, questions arises about the functional capabilities to the ethics behind creating such powerful and potentially life-consequential technologies. As such, it makes sense to spend time considering what we want these systems to do and make sure we address ethical questions now so that we build these systems with the common good of humanity in mind. Following 9 ethical issues have been identified at World Economic Forum–ASEAN Summit 2018 titled "Top 9 ethical issues in artificial intelligence: -

(i) **Unemployment**- what happens after the end of jobs

(ii) **Inequality** - how do we distribute the wealth created by machines

(iii) **Humanity** –how do machines affect our behavior and interaction

(iv) **Artificial stupidity** – how can we guard against mistakes

(v) **Racist robots** - how do we eliminate AI bias

(vi) **Security** – how do we keep AI safe from adversaries

(vii) **Evil genies** - how do we protect against unintended consequences

(viii) **Singularity** – how do we stay in control of a complex intelligent system

(ix) **Robot rights** - how do we define the humane treatment of AI

## 4.6 Application of AI in India:

National governments and international governance agencies around the world are deploying AI-based solutions for a wide range of issues that are central to public policy and welfare. The predictive powers of AI and its flexibility, lends AI solutions to a range of challenges facing society. Governments can reach the underserved and deliver more efficiently, by judiciously fusing AI into its operations. A task-based analysis26 finds that AI can speed up governance tasks by 20 percent, freeing up to 96.7 million hours and consequently saving $3.3 billion for governments. Other concrete instances of AI's capabilities can be observed in the area of public utilities. For instance, Australia's public sector company, Melbourne Water which operates across the city of Melbourne, is using Machine Learning techniques to manage the differential rates at which its water pumps are running so as to maximize efficiency in its water distribution system27. In India, AI is demonstrating its potential to enhance law enforcement capabilities through Deep Learning based applications such as facial recognition systems, which are being used by law enforcement agencies to efficiently track missing children28. Delhi Police has partnered with ISRO to develop an analytical system called Crime Mapping Analytics and Predictive Systems (CAMPS) which helps them ensure internal security, also controlling crime. Similar programs are being adopted in other states such as Jharkhand and Karnataka29. Dubai police has signed an MoU with the Indian startup Staqu for its predictive policing solutions which were already piloted and adopted by states such as Rajasthan, Punjab and Uttarakhand. Defense Services in India use AI for intelligence,

surveillance, etc, though several of these projects are still in the pilot or testing phase. The International Telecommunications Union (ITU) published a report on the United Nations' activities on AI30, which compiles how different UN agencies are deploying solutions to achieve various Sustainable Development Goals (SDGs). For instance, the International Labor Organization (ILO) initiated a project that uses Big Data based AI algorithms to monitor incidence of child labor in Kyrgyzstan. The United Nations Children's Fund (UNICEF) is using AI to generate insights on the spread of an epidemic and Deep Learning methods to increase empathy for victims of natural disasters31. In India, we find innumerable AI applications focusing on developmental outcomes. A recent media report stated that 11% of AI startups in India were focused on the education sector. These include Toppr, Edu Gorilla, Embibe, etc32. Other critical areas of application include `securing lives of the disabled, healthcare, child nutrition, etc. IIT Kharagpur has developed a solution that filters fake news and alerts users during disasters. GnoSys, a smartphone application developed for the deaf and mute, uses natural language processing, neural networks, and computer vision to translate gestures and sign language into speech. The app is expected to change the life of an estimated 18 million people in India who are hearing impaired. AI is claimed to have become critical to governance in the 21st century. In the era of Big Data, AI technologies such as sensors and Machine Learning, can provide real time insight on the efficacy of government regulations and lapses in regulatory oversight. The government in India has publicly acknowledged the role of AI in enforcing good governance and proper regulations in India.

# Chapter - 5

# Artificial Intelligence Outcomes In 5g

At a time of increasing complexity for mobile communications service providers, driven by deployment of 5G and the Internet of Things (IoT), this report examines the crucial role of artificial intelligence (AI) in helping to maximize returns on network investments. It explores the extent to which service providers have adopted AI, and looks at their plans for further deployment. The importance of AI in developing and underpinning customer relationships is also examined. It is our belief that AI will open up exciting opportunities for the mobile communications sector, as it can be utilized to create a more personal approach for customers, while helping to manage the costs of deploying and maintaining networks. AI is creating both benefits and challenges for service providers at the advent of 5G. AI is being adopted in networks AI is being embraced by service providers around the world, according to our research. More than half of service providers – a total of 53 percent – expect to have adopted AI within their networks by the end of 2020. Some are working to an even shorter timescale, and expect to have adopted AI by the end of this year. A further 19 percent are looking at an adoption timescale of within 3 to 5 years. The main areas in which service providers are already seeing value and return from AI are in building new revenue and enjoying operational cost savings. AI will be vital to customer service Enhancing customer experience was identified by 55 percent of service providers as a key area where AI is presently having the greatest impact within core network activities. In addition, 68 percent highlighted enhancing customer service as a business and operational objective over the next 3 years. A further 72 percent agreed strongly that AI will be important in enabling monetization of new network technologies and providing a better service to customers. AI will help recoup network investments At the advent of 5G, service providers are making huge investments in their networks to enable the new use

cases that 5G offers. AI will help operators recoup these investments more quickly. Service providers believe the highest potential return from AI adoption will be in network planning (70 percent) whilst 64 percent intend to maximize their returns by focusing their AI adoption efforts on network performance management. AI is creating network data challenges Embracing AI in networks is a challenge for service providers. The main concern identified by 71 percent was defining and implementing standardized interfaces. Other difficulties highlighted included data quality (65 percent); excess of data from too many sources (59 percent); problems finding indicators of degradation or compromised assets (59 percent); storage of data in too many systems (56 percent); and lack of single ownership or oversight of the data.

AI assesses data and quickly delivers analytical outcomes to users. It encompasses Machine Learning (ML), which analyzes raw data and autonomously looks for patterns that can yield further insights. Already, sectors such as manufacturing, healthcare and banking are capturing the benefits of AI. For service providers, AI offers opportunities that need to be built jointly with infrastructure providers on a case-by-case basis, with a common goal to more effectively manage complexity and optimize network performance. Our research has revealed service providers around the world are presently at various stages on their journey with AI. Many service providers are already concluding successful trials on using AI in their networks. Only 12 percent feel they have a detailed knowledge of AI's application. However, 49 percent considered themselves to have a fairly detailed knowledge of AI application. More than half expect AI to be adopted in their networks before the end of 2020 (a total of 53 percent globally) and there is a general expectation (55 percent globally) that the benefits will be evident within 1 to 2 years. The majority of service providers are at the stage of testing AI, with 48 percent focusing on AI to reduce capital expenditure. A further 41 percent are focusing on using AI for optimizing network performance, and 35 percent for new revenue streams.

The highest current use of AI among service providers worldwide is in service quality management (17 percent) and operational cost savings (16 percent). The broader context for the interest being shown in AI by service providers is that 5G is expected to cover more than 40 percent of

the world's population by 2024,1 and total mobile data traffic is predicted to have increased by a factor of 5 by this date. Early adopters of AI among service providers will undoubtedly gain an advantage, as they will be well placed to deal with new challenges that result from the proliferation of additional devices following the introduction of 5G. This is because the 48% 41% 35% Capital expenditure reduction Optimizing network performance New revenue streams Figure 2: Focus of service providers testing AI advent of 5G will make network topologies relatively complex, with small cells and new antennas making usage patterns more difficult for humans alone to predict, and current radio propagation models becoming more complex to compute as a result of new radio spectrum bands, denser topologies, Massive MIMO and beamforming. Service providers around the world are observing improved reliability for customers as the area in which AI is currently having the greatest impact upon core network activities. The research conducted for this report has also revealed that AI is presently facilitating improvements ranging from simplifying network evolution to improving performance across existing networks.

Continuous improvements to efficiency are essential to any business sector, and the mobile communications sector is no exception. The arrival of 5G will be characterized by improved speed, consistency, reliability and capacity. Features such as advanced load management will enable service providers to effectively manage the network traffic, ensuring network performance has minimal to no impact with additional devices coming over the networks. Service providers will be able to achieve successful management of network performance by developing cognitive and predictive AI algorithms. The rapid expansion of advanced IoT devices will need real-time latency, and successful adoption of AI will facilitate faster, more responsive, available-on-demand networks. However, the benefits of AI extend beyond cost-management and network-management efficiencies. Enhancing user experiences is expected to be one of the many notable benefits of AI-managed services on the networks. In our research, network capacity planning/management emerged as the top area where operators see opportunities in terms of implementing and adopting new AI use cases. This was followed by reduction of time in network planning. The results of our research

highlight the strong appetite among service providers for building AI reasoning-based systems that can enable the self-healing, self-optimizing and self-configuring networks of tomorrow. The areas where service providers indicated how they are focusing their AI adoption efforts. It shows how increased reliance on smart automation enabled by AI will be an investment for service providers, with return on investment (ROI) visible in significantly reduced operating costs.

In order to maximize the potential of AI, there needs to be effective collection, structuring and analysis of data to ensure clear and actionable insights for network development and improvement. This is an area of concern among service providers and infrastructure vendors across the globe, with 71 percent expressing concern about defining and implementing standardized interfaces. As part of our research, we asked respondents to provide their views on whether their company was collecting data effectively. It became apparent that data quality was an issue. This was cited by 65 percent of respondents globally, and 89 percent in North America. Other concerns expressed globally included an excess of data from too many sources (59 percent); problems finding indicators of degradation or compromised assets (59 percent); storage of data in too many systems (56 percent); and lack of single ownership or oversight of the data (55 percent). At the heart of these concerns is the fact that traditional approaches to data analytics have been based upon centralized and generic analysis tools. These are unsuitable for addressing the increasing complexity and vast volumes of data in 5G networks. The barriers highlighted in our research (data quality, multiplicity of sources and systems) are indicative of the limitations of the traditional approach to data analytics. AI-enabled networks employ advanced data analytics that make systems smart, adaptive, self-aware, proactive and prescriptive. These can play a key role in reducing associated operating costs and in addressing many of the barriers that service providers have indicated are preventing insights from data being acted upon.

AI will bring significant benefits to mobile communications, notably cost and network management efficiencies, and improvements to customer experience. However, in order to make the most of the opportunities, service providers will need to take a proactive approach which includes:

1. Building standardized interfaces to access relevant and actionable data
2. Exploring ways of using ai to optimize customer experience
3. Running early trials with new customer segments to identify ai opportunities
4. Examining use of ai and automation for network operations, including planning and optimization
5. Ensuring early adoption of new solutions for ai and automation to facilitate introduction of new use cases

The rollout of 5G will be faster than that of any previous "G". We predict that 5G coverage will go from almost zero today to becoming available to 40 percent of the world’s population by the end of 2024. In the same time frame, we expect 1.5 billion 5G subscriptions for enhanced mobile broadband. 5G will enable capabilities that a few years ago were only dreamed of by visionaries. Massive machine type communication Massive machine type communications (mMTC) will allow cities, transportation and infrastructure to transmit real-time data for improved maintenance and greater operational efficiency. Vehicle-to-vehicle and vehicle-toinfrastructure communication will make roads safer, protect the environment, and allow buses and public transportation to run more efficiently. Sensors embedded in roads, railways and airfields will communicate with each other and with smart vehicles, enabling new services and business models. Critical machine type communication 5G introduces the ability to remotely control devices and heavy machinery, unlocking the potential for improved medical services and surgeries that would otherwise remain unavailable to rural communities. Heavy machinery can be controlled remotely, improving safety in hazardous environments. Industries like manufacturing and mining will experience better efficiency and reduced costs. The IoT era will become a reality by breaking constraints and capturing information in new ways. For instance, sensors will be implemented throughout farms, allowing crops to communicate moisture and fertilization needs. Utility companies will be able to monitor and report energy usage, improving the reliability and sustainability of energy production and distribution. Enhanced mobile broadband 5G will make it possible for customers to download 4K

movies in seconds without a Wi-Fi connection. It will provide broadband in crowded areas like concerts, sporting events and festivals with abundant capacity, telco reliability and lack of interference from surrounding frequencies. Live TV broadcasts and sporting events will be immersive, as if you were at the event. 5G will dramatically improve connectivity indoors and out, offering high quality of service (QoS) broadband even in challenging network conditions. Fixed wireless access Wireless radio links will replace leased lines or physical cables to provide fixed access between two or more locations, making it faster and cheaper to provide or change services with customers.

Critical services and infrastructure control The high reliability and low latency of 5G unlocks the ability to control critical services and infrastructure for public safety, special events, traffic management and weather. Government bodies, city management and utility companies will be able to connect to millions of networked devices, making real-time, intelligent and autonomous decisions. 5G will become the backbone of IoT, connecting devices in ways we never thought possible. Smart cars will communicate with traffic lights, users will immerse themselves in augmented reality and 360-degree games and movies, and the tactile internet will be enabled through the transmission of touch and texture. Service providers will be unable to economically support IoT device-to-device and device-to-human communication by simply upgrading their existing network services such as evolved packet core (EPC). To participate in the 5G ecosystem, they will have to transform their infrastructures with these technologies. Radio evolution Access-agnostic mobility centralizes registration, authentication and management of communication sessions for all devices and networks. A network slice (see below) can be provisioned for fixed services, another for mobile, and another for converged. Instead of limiting communications within the narrow bands of radio frequencies assigned in the slow and expensive traditional manner, flexible spectrum usage will make seamless communications possible, through portions of the spectrum that make the most economic sense or comply with relevant security or governance policies. This flexibility will be aided by millimeter wave and adaptive beamforming, which improve spectral efficiency and peak rate capacity. Virtualization Traditional network

services hosted on vertically optimized hardware are being replaced by VNFs hosted on cloud infrastructures. This virtualization will spread throughout the telecommunications infrastructure to eventually include radio access networks (RAN) – see below. However, to be competitive in the 5G ecosystem, telecom services will all have to be reconstituted as cloud-native applications composed of microservices. Software-defined networking and network slicing A software-defined network can dynamically allocate network bandwidth to applications. Whether to meet performance, cost or other requirements, network slicing within a software-defined network provides dramatically greater flexibility at lower cost than manual re-cabling. Cloud-native network functions Cloud-native network functions allow service providers to launch applications in days instead of months with the reliability and security expected by the telecom industry. End-to-end service management A single provider takes responsibility for every aspect of a service to a customer, including purchase, monitoring, repair, upgrades and life cycle management, so that the customer has a single point of contact. Edge (distributed) computing Edge computing moves the processing of data and functions to the point in a network architecture that provides the maximum benefit, whether low latency, lower cost or compliance with government regulations. RAN-as-a-service RAN are delivered as a cloud service and managed alongside compute, storage and network resources within the same cloud infrastructure. Multi-site domain services These manage the distributed IT and telecom environments of a customer from a central location in order to provide end-to-end incident management, optimize performance and expenses, ensure security and compliance, and resolve irregularities. Security, reliability and availability Security, reliability and availability can be provided at cloud scale, encompassing distributed/edge computing and devices, according to telecom-industry standards. 5G will also require a restructuring of the radio spectrum in the face of political pressures, geographic difficulties and corporate agendas. As RAN evolve onto either existing clouds or a cloud of their own, network topology will have to evolve alongside them and become dynamic. This is because the heart of the global telecommunications infrastructure is going to transform from physically hosted to software-controlled.

Basic services are becoming commodities New "over-the-top" service providers are commoditizing connectivity and eroding the profitability of traditional value services such as voice, video and text messaging. Revenues are being pressured by large players who have the advantage of economies of scale. Simple examples are Google, whose basic product is free to users, and Facebook, whose entire platform is free to users. They earn tremendous revenue on their add-on services precisely because their installed base is so vast. These two forces are commoditizing basic services, so if you try to compete only with basic services, you get caught in a race to the bottom. Partner ecosystems are replacing value chains The industry is transforming from traditional value chains to partner ecosystems. Instead of offering customers a single, fully featured platform, you will partner with other vendors to offer different combinations of services. Some of those services you will build in-house, some you will resell for other vendors, some you may co-develop with partners. Just as important, you will reshuffle those partnerships and services quickly as business needs change. Relationships are becoming digital Industrial customers are growing accustomed to carrying out typical account management tasks through digital interfaces instead of human account representatives. They order new services, manage existing services, perform their own self-care, and handle end-to-end provisioning of the network services they offer their customers. They deploy analytics to gain insights into customer engagement, and they target upsell recommendations based on customer preferences derived from those analytics. New development models are increasing the pace of innovation The rapid evolution of technologies and customer expectations is forcing even profitable business models to change much quicker than they used to. Because services can have much shorter life cycles, they must be launched faster, with cost containment from the beginning to obtain a rapid return on investment. Service providers must become skilled at migrating customers from the old to the new. Model-driven development and management as well as cloud-native development are primary forces contributing to the fast pace of innovation. Open source is complementing standards bodies Open-source technologies such as OpenStack have established sufficient market share in telecom services to become credible alternatives to traditional standards bodies such as ETSI. Open source offers a number of

advantages: instead of several vendors developing different versions of the same capability, an open-source community develops the common aspects, and each vendor can focus on writing their own set of more advanced and differentiating features. The result is more efficient product development, since open-source projects can leverage a far greater community and broader perspective of developers than is possible within a single vendor. Open source is also proving a useful distribution channel for technologies that vendors would like to see more widely adopted, such as AT&T's ECOMP platform for network automation. Open source is blurring support boundaries When you host telecom applications from multiple vendors, sitting on a multi-layered cloud stack, within a software-defined cloud infrastructure, that runs hardware which is also from multiple vendors, support boundaries can become difficult to establish and maintain. Add open-source components, some of which are delivered by the vendor and some by the operator, and support boundaries become impossible to maintain.

# Chapter - 6

# Conversational AI In Telecom

A virtual assistant should be able to recognize all the intents without being constrained by budget. Most tools in the market support strong intent recognition as it's considered more of a commodity functionality today.

## 6.1 Intent Recogntion:

CLOSE INTENTS Answers often need precise understanding to deliver an exact response. For example, "I cancelled my flight - can I get a refund?" and "You cancelled my flight - can I get a refund?" are both about flights being cancelled, but they call for very different responses. And follow up questions such as "what about my seat fee?" should be understood within the same conversation, without the user being sent down new one-way flows.

**Negative Intents** These should be accounted for to allow for exceptions to general rules and this is one area where out of the box classifiers struggle. Particularly with modern phrasing, you need a way to identify these, e.g. a user saying, "I'm really happy with the service – not!"

**Exceptions** Using another flight example, a passenger may ask whether a particular animal is allowed on board. The general answer is no, but there are likely exceptions for small dogs, cats and service animals. How much effort is required to build a general recognition and then add exceptions

**Multiple Intents** A good conversational AI solution will be able to handle multiple intents and respond in the best order, even when they are not presented as such. If a user wants to install the airline app on a new device, but has also forgotten their password, the solution must be able to understand, prioritize and respond to both requests like a human would.

## 6.2 Context:

This mutually affects consumers and companies alike, as the former have queries and demands but must find a way to get through to their service providers, and the latter need to find ways to deal with a surge in inbound queries. Outsourcing is not a solution Before the crisis, many telecommunication companies relied heavily on contact centers to provide customer services and sales interactions. In many cases, these enterprises looked to reduce costs by offshoring contact center resources and many intensive back-office processes. When Covid-19 induced lockdowns many telecoms were unable to use their centers overseas. Shifting the burden to onshore centers was not the solution to the problem. Enterprises were not equipped to address the increasing demands for new domestic call centers while handling the sharp reduction in staff and with no way to hire or train new recruits. The lack of access to workers goes in contrast with increasing customer demands for 24/7 services and via the multiple digital channels at their disposal. This is where telecoms have focused on the importance of digital self-service, automation and artificial intelligence to enhance contact center case resolutions and provide greater customer insights and real-time decisions. New customer requests need quality interactions Modern consumers are tech-savvy and have high expectations of the brands they interact with. The telecom industry has a growing frequency of interactions between customers and providers. With the telecommunications industry being as the forefront of digital transformation, both as an industry witnessing large-scale change in its market and as a key driver of worldwide digitalization, telecoms users have also been prominent players in consumer tech adoption. They are most likely the consumers with the most advanced and demanding expectations. The accelerated pace of technological development is changing customer behavior and enhancing interest in interconnected, smart and automated features. With the introduction of Conversational AI, this decade will see more than a third of the population belong to a generation that has replaced display-focused communication with conversation-focused platforms.

## Context

A solution should easily incorporate explicit and implicit context.

## Implicit Context

Implicit context is knowledge you have about a user without their needing to mention it, such as a logged in user's account details or mailing address. Explicit context is something the user has mentioned (e.g., "I'm bringing my daughter along") as well as conversational context – "how much legroom do I get in economy", followed by "what about business?". The second question makes perfect sense in the context of the first, but on its own has no meaning.

## Interruption Handling

Users will interrupt, divert or change topics mid-way through a query. If our travelling user is enquiring about redeeming their loyalty points balance, then suddenly breaks off to ask about luggage allowances, the solution must be able to answer the second query and then resume with the points redemption query without requiring high levels of potentially expensive professional services to undertake complex coding across multiple locations.

## Future Proofing

Understand how the model is built, tuned and optimized. Is the solution a black box, solely reliant on feeding it more and more training data to improve? Who provides the training data? How is the model protected from degradation over time? Does the platform itself help? Consider, too, who has access to that data – remember that some conversational AI providers are already or might in future be competitors.

Furthermore, the different factors that give enterprises a competitive edge have also been altered. Where cost of operation was once king, continuity of service will be the new master. Telecoms who have yet to adapt to these new changes will look to the winners and see what they can learn from them. This will have huge implications across disparate technologies, from infrastructure and security to business process automation (BPA) to Conversational AI. There will be greater digitalization across all enterprises adapted to consumer needs and

commodities. Telecoms will ensure that customer engagement and satisfaction, a clear differentiating factor in the market, is of the highest standards by staying in the front line when it comes to innovation.

## 6.3 External Systems :

How are your backend systems integrated into the solution, e.g. how might a ticketing system be accessed to provide automated support? Does the solution separate out technical coding from conversational design? Can integrations be done in-house with your own resources or will it require specialist vendor professional services time?

## 6.4. Conversational Data:

What type of conversational data is available and how can it be accessed.Is access to all data included in the license fee or are additional costs involved.

### Aggregated or Voice of the Customer

Does the solution provide only general statistical data (volume metrics, intents recognized and similar), with no actionable insights? Or can it access granular data right down to individual conversations, where actual queries, concerns, likes and sentiments are discussed? Keep in mind that while statistical data lets you know how many people are using your solution, it's the granular conversational data that lets you know how well it's performing, find areas for optimization and extension as well as identify potential business value.

## 6.5 Interrogation:

Can the data be interrogated at an individual input level? Are you required to use vendor-provided tools, or can the data be surfaced and analyzed with your existing BI tools?

**Data Access and Flexibility** As you require new dashboards and reports, can your own data scientists and business analysts create them, or will you be reliant on vendor professional services? Does the platform provide a comprehensive query language for deep interrogation of data and can data be exported as well as linked into your data warehouse?

What export formats are supported? Are there any additional costs for this functionality?

## 6.6 Data Ownership:

Who owns the data and who has access to it? Bear in mind that some vendors on your RFP may already be competitors or become competitors in future. Automation and Conversational AI platforms Even before Covid-19 left its mark, the telecommunications industry was persistently seeking ways to expand its business value while adapting to new changes within its sector. Consumers were also demanding more from their providers. As new technologies emerge, the fastest growers in telecoms are adopting these innovations to provide better value to their customers and their businesses. The growing demand for services during the recent pandemic is good news, but it also means that there is a rising number of consumers with high expectations requesting immediacy, personalization and quality customer satisfaction and experience. We have seen that businesses understand the importance of automation, self-service, and solutions that work around the clock. However, providing phone and internet services isn't enough. One of the most recent innovations within the telecom landscape that is helping with this issue are chatbots. When looking for conversational solutions, telecoms are no longer looking for artifacts that serve single solutions, but for omnichannel and multilingual platforms that they can have control over. These platforms must also go beyond experimental levels and be at enterprise strength. There is enough market research available to determine that decision and customer requirements have been set. Enterprises need industrial-grade applications that are humanlike, capable, and robust while providing scalability, multiuse, omnichannel and multilingual facilities that are expected in proficient platforms. They need intelligent platforms. Intelligent platforms that enhance customer engagement The telecommunications sector has accelerated the use of new digital technologies to deliver the most advanced, intelligent and humanlike virtual assistant. Telecoms that are quickly and effectively deploying conversational AI are gaining a competitive edge. Companies are seeking ways to improve the efficiency of their customer service, minimizing human error or employee absenteeism and resolving customer queries swiftly to reduce operational costs. But the best conversational AI

platforms provide more than that.. A POST-COVID-19 WORLD We are living in genuinely unprecedented and challenging times. The effects of Covid-19 have had a noteworthy impact on all industries, and on the Telecommunications sector in particular. Even after things have returned to normal, the new normal will bring about irreversible changes that will directly affect the telecom industry. Can the data be augmented with additional information after the fact, accommodating changes over time? For instance, you might forget to include sentiment analysis in an initial deployment – once it's added, can you also go back and add that information to previous conversations.

## 6.5. Data Security And Privacy

Describe how your solution addresses requirements around data security and privacy. Data protection regulations (GDPR, CCPA, APPI, etc): Are both the vendor and their technology compliant with regulations applicable to you? How easy is compliance – does the vendor provide tools allowing you to act yourself, e.g., generating a report on user data for a GDPR or CCPA request? Or will you be required to go back to the vendor whenever you need to take action? Are there additional costs involved for compliance?

## 6.6 Vendor Compliance

Is the vendor data regulation-compliant in all relevant territories? Consider, too, your end users – you may not be based in the EU/California, but if your users are, you must comply with the law in that area. HOSTING How flexible is the hosting model – can the vendor both provide cloud hosting and support on-premise deployment? If the latter, are any connections still required back to the vendor's servers? Can they support mixed hosting? If cloud hosting is used, what data security options are available and what impact do they have on you and the vendor? Can you easily switch from one model to another and what costs are associated with that? DATA PRIVACY What legal and practical provisions does the solution have for personally identifiable information (PII). How have the requirements for data deletion, masking, pseudonymization and anonymization been fulfilled? Are there tools available for this or is it a manual process? What data goes into logs and

can it be selectively disabled? Who has access to the data. A POST-COVID-19 WORLD We are living in genuinely unprecedented and challenging times. The effects of Covid-19 have had a noteworthy impact on all industries, and on the Telecommunications sector in particular. Even after things have returned to normal, the new normal will bring about irreversible changes that will directly affect the telecom industry

## 6.7 Artificial Intelligence:

AI can proficiently assist customers in various ways. While simple bots can be scripted for little more than answering FAQs, more advanced bots and virtual agents can use machine learning and natural language processing to recognize customer intentions. This means that chatbots can analyze the relationship between words and discover what a customer requires and subsequently hold a conversation. This can also be done through various channels, providing a seamless and contextual experience that provides relief to support personnel and increases customer satisfaction and company value. Personalized and tailored assistance to boost sales One of the world's largest telecommunications companies that provides a range of services including voice, messaging, data and fixed communications has used the Teneo platform to develop a variety of applications that deliver an enhanced online self-service experience to its customers driving customer engagement. Delivering Personalized 24/7 Support One such implementation is a digital employee who resides on the company's website. The virtual assistant is a trustworthy, reliable employee that customers turn to for personalized, round the clock support with a wide range of issues. As the Teneo platform enables users to quickly and easily develop applications, the company swiftly built sophisticated dialog flows that enabled the assistant to resolve complex technical support queries as well as simpler, but time-consuming issues such as a change of address. The personalization of user interactions means that the conversational bot can boost online sales by advising on tariffs based on customer preferences and connecting to third-party data via APIs to provide further information.. A POST-COVID-19 WORLD We are living in genuinely unprecedented and challenging times. The effects of Covid-19 have had a noteworthy impact on all industries, and on the Telecommunications

sector in particular. Even after things have returned to normal, the new normal will bring about irreversible changes that will directly affect the telecom industry.

## 6.8 Language Capabilities:

How do you implement a new language? NEW LANGUAGES What is the process, cost and timeline for adding support for a new language? How open is the vendor to adding support for a language you need, when you need it?

**Existing Languages** How are existing languages enhanced and updated? What standards are met for maintenance? Are languages versioned? Can you extend the model with your own vocabulary and if so, can you do this yourself or are you reliant on the vendor?

**Language Quality** How is new vocabulary added? How is the depth and breadth of languages checked? What is the frequency of language updates? Are variants supported, e.g. Portuguese Brazilian, Swiss German or the various Latin American Spanish variants?

**Rollout** How can a solution be rolled out in new languages? Do you need to rebuild the entire solution in the new language or is there a method to inherit solution structure and just perform necessary language localization (this also applies to solutions in the same language but in different regions, where legal, compliance and other factors can have an impact)? Does the platform help manage the same solution in multiple languages or is it a manual process? Consider the case of 10 bots in 10 languages – managing it manually would require a full-time team.

## 6.8 Enterprise Suitability Training Data:

What data to you have for training a solution? Is it real or simulated data? If you supply domain data, will other customers, i.e. your competitors, be able to use it for their solutions? Can you get started without training data? Can the platform itself generate training data from a deployed solution? COLLABORATION How open to suggestions or inputs for product features or development from customers is the vendor? Is the vendor willing to change development direction if you urgently need a new functionality?. A POST-COVID-19 WORLD 8 Chatbots

allow customers to manage requests in a faster and more efficient way and act as a listening channel from which telecoms can better understand their customers and subsequently facilitate the delivery of personalized information, offers and services. The benefits are palpable: higher lifetime value of customers, the ability to contextualize products and services, and increased brand loyalty. This type of deployment is crucial for telecoms to carry out their digital transformation and thus be able to compete with the giants of the industry, but what is the best use for Conversational AI in telecommunications? Chatbot Use Cases in Telecommunications Enhance Customer Support Telecom chatbots can help clients find what they are looking for quickly and 24/7. Apart from saving time and resources by directly replying to FAQs or simple and repetitive issues, chatbots can redirect customers to appropriate departments when matters are more complex. By picking up useful information from customer requests, the feedback provided by chatbots can help the support agent resolve the query. Additionally, chatbots are helpful in crises such as Covid-19, where major problems affect many clients in a specific moment. They can handle mass requests at the same time and store information so that clients do not need to wait in line or repeat and explain their problems repetitively. Chatbots produce smoother experiences for customers, particularly when dealing quickly with issues that can span different departments. That way, customers feel like they are having one seamless conversational with a brand that remembers their details. These actions will result in considerable growth in customer retention. Resolve Technical Issues Customer experience is intrinsically linked to business value. Customers searching through forums or tedious FAQs are often frustrated and prone to lose their loyalty to a telecommunications company. Conversational chatbots allow users to resolve their technical issues and find that they can rely on the company for assistance, no matter how technical it may be.

## 6.9 Enterprise Features:

Does your solution include features such as: version control, role-based permissions, commenting, channel support, rollback etc. Are these included in the licensing costs or is there hidden cost associated with them? USER AUTHENTICATION Can the platform be integrated into existing authentication tools or is it separate? What authentication/

authorization is included out of the box and what is available for an extra cost? SCALABILITY How does your solution scale, both technically and from a business perspective? In addition to handling increased usage, you will also want to scale to new languages and regions. This can mean an exponential increase in management overhead to keep solutions in sync – how is this handled? MULTI-USER FUNCTIONALITY Is the platform truly multiuser, allowing multiple developers to work on the same solution or is it a case of "she who saves last wins". Are changes logged with user, date/ time and comments? Describe how users can work concurrently on content.

## 6.10 Hosting and Connectivity

What hosting models are available for your solution?

**Hosting Flexibility** Are flexible hosting options available – cloud, on-premise, mixed, on-chip? Is transition from one hosting method to another possible now and in the future, and if so how and what costs are involved?

**On-Premise Hosting** Does on-promise hosting truly stand alone from your servers or is there still a connection back to the vendor's server? Can it be entirely managed in-house or is there still vendor reliance?

**Hosting Changes** What is the pathway and what are the cost implications of changes to hosting arrangements? Can this be done in-house, or does it require vendor professional services support? If cloud-hosted, what provisions are there for business continuity and disaster recovery Meeting enterprise Conversational AI needs with Teneo's multilingual platform. One of Switzerland's largest telecommunications and TV providers, serving 2.75 million private customers, has launched a new dialogue platform using Teneo to deliver conversational solutions 24/7 that are easy to deploy, are integrable with other components and adapt to Switzerland's multilingual environment. The company receives over 10million customer requests per year over eight channels. So, they sought omnichannel and integrated solutions that were available 24/7 and were personalized and seamless. Importantly, they wanted a platform that could be delivered in English, French, Italian and German as well as providing support in SwissGerman. "We enable everybody to get in touch in the most natural way," said the Product Owner and Dialogue

Manager at the company. Best of breed solution Teneo's usability, scalability lexical resources and multilingual support were decisive as the telecom deployed the program for three key initiatives: — A TV-Box to deliver a personalized entertainment experience — A Conversational IVR to provide Voice assistance for natural customer interactions — A Chatbot to improve dialogue flow and optimize chat on multiple channels.. Even after things have returned to normal, the new normal will bring about irreversible changes that will directly affect the telecom industry.

## 6.11 CLOUD Apis:

Does your solution connect to existing APIs to integrate other systems or does it require custom API builds? Can you use in-house resources or are you reliant on vendor professional services? Are there any costs associated with using APIs?

**Existing Deployments** Can the solution be connected to existing deployments out of the box? If not, describe what extra costs and time it will take to connect these existing deployments.

## 6.12 Total Cost of Implementation:

Outline a typical/estimated total cost of implementation and typical ratio of license: implementation costs?

### Implementation Resources

Can you take full control or is implementation reliant on vendor's professional services resource? Can you work with your preferred system integrator? MAINTENANCE RESOURCES What types of resources are needed for implementation and maintenance? How much can be done in-house and how much must be done by the vendor?

### Professional Services

Outline standard professional services costs and describe typical ratio of professional services days: software costs. Are there hidden costs in additional or advanced capabilities?

# Chapter - 7

# Artificial Intelligence In Wireless Communication

Global demand for wireless communication networks continues to increase, mainly due to the evergrowing numbers of wireless users and new emerging wireless services. The fifth generation (5G) and beyond 5G (B5G) wireless networks are expected to be developed in the future and offer higher data rates, improved coverage, better cost efficiency, resource utilization, security, adaptability, and scalability [1]. Artificial intelligence (AI) technologies have the potential to efficiently solve unstructured and seemingly intractable problems involving large amounts of data that need to be dealt with in the design and optimization of 5G and B5G wireless networks.

AI is “the simulation of human intelligence processes by machines, especially computer systems” [2]. It is usually defined as the science of making computers perform tasks that require intelligence like humans. Whereas AI is a broader concept of machines being able to carry out tasks smartly, machine learning (ML) is a current (probably the most popular) application of AI that enables machines to learn from large amounts of data and act accordingly without being explicitly programmed. As a special type of ML, deep learning studies artificial neural networks (ANNs) that contain more than one hidden layer to “simulate” the human brain. Currently, deep learning is one of the most widespread ML methods as it has successfully been applied to different fields such as the computer vision, speech recognition, and bioinformatics. Current cellular networks designed and operated based on previous postulates may systematically fail to enable future communication services, since they cannot keep pace with the data explosion and the underlying complexity of the generated data while

guaranteeing the required capacity, reliability, and adaptability. Thus, the network cannot quickly react and anticipate events that might deteriorate communication services in real-time. However, as most AI algorithms and applications are not specifically designed for wireless communication networks, it is hard to directly apply existing AI algorithms to B5G networks.

AI technologies will not only reduce or even replace manual efforts for the network development, configuration, and management, but also deliver better system performance, reliability, and adaptability of communication networks by making real-time robust decisions based on predictions of the networks and users' behavior. ML, as a typical AI technologies, is widely expected to rapidly become a key component of B5G communication networks. It will make a full use of the big data to overcome the challenges of designing and operating B5G networks. Potential benefits of introducing ML into communication systems include the following. Firstly, channel and interference models are extremely complicated in reality due to the dynamic nature of wireless communication channels, especially in B5G scenarios. ML techniques may automatically extract the unknown channel information by learning from the communication data and prior knowledge.

Secondly, as the density of wireless access points continues increasing, there is an urgent need for global optimization of communication resources and fine tuning of system settings. However, the enormous amount of resources, system parameters to be optimized, and their coupled correlations render these tasks notoriously difficult to solve using existing approaches. In contrast, sophisticated ML algorithms, e.g., deep learning and probabilistic learning methods, may be able to model the highly non- 2 linear correlations and estimate (sub-)optimal system parameters.

Lastly, ML will realize learning-based adaptive configuration of networks by finding out behavioral patterns and responding timely and flexibly to various scenarios, e.g., anticipating traffic and planning ahead rather than simply reacting to unexpected events. Large-scale Sensing via Massive Radio Interfaces.

The use of large antenna arrays offer not only the unprecedented performance in terms of reliable and high-rate communications (as exploited in massive MIMO), but also provide enormous amounts of baseband-level data that can be used to make inferences about the environment. Emerging more novel use cases include inference problems, for example, detection of the presence of moving objects, estimation of the amount of traffic on a road, counting of the number of persons in a room, or guarding against intrusion in protected spaces. Particular technical challenges that lie within reach are the sensing of open spaces, indoor venues, and even through-the-wall.

There are emerging commercial use cases and also many applications in security, surveillance, and monitoring. ML algorithms are particularly suitable to analyze the vast amounts of data generated by large antenna arrays, especially massive MIMO arrays, as typically parametric models are unavailable or inaccurate, hence classical estimation/detection algorithms are inapplicable. More specifically, in terms of algorithmic 5 approach, deep learning networks and methodology from image processing and video analytics may offer the most promising path. It is important to note the distinction to conventional radar imaging, where the objective is to create an image or map of the environment, whereas the goal of emerging large-scale sensing is to extract specific features of the dynamics of the environment and make inference about specific phenomena.

Important future research directions should include both pertinent physical modeling work and the construction of an algorithmic foundation that exploits relevant ML tools. Trained deep neural networks represent an important technology component in this regard, but also various forms of dictionary learning might be used. Simulated channel models should be used for evaluation, along with experimentally obtained real data. Through the use of these techniques, research along this direction could significantly advance the state-of-the-art in sensing of open spaces, indoor venues, and through-the-wall and accomplish inference tasks that are impossible with conventional model-based signal processing. Another application that may benefit from the technology is gesture recognition, especially when implementing sensing at higher frequencies.

In current communications applications, signal processing and ML algorithms are typically executed centrally. An archetype architecture is the cloud-radio access network (C-RAN), where joint estimation and data processing for all network devices is performed at a central unit (e.g., the cloud). In the presence of a large number of devices and communication limitations on the fronthaul/backhaul links, however, 9 various network functions should be executed locally or with minimal information exchange with the cloud. Therefore, of central importance is the provisioning of a decentralized functional architecture, which adapts dynamically on the network requirements. As lightweight deep learning model can be applied to cloud, fog, and edge computing networks.

The cloud network is the data and computing center, the fog network includes many nodes, and the edge network contains enormous end users and devices. In parallel, there is the need for decentralized learning, classification, and signal processing algorithms, which seamlessly adapt to the number and the type of the information sources, considering the available communication bandwidth. In the presence of a dynamic edge computing architecture, the advantages of decentralized and centralized algorithms should be combined, thereby trading-off complexity, latency, and reliability. This requires integration and further development of methods for data fusion, compression, and distributed decision-making.

In the distributed setting, there is also the need of developing solutions that are capable of learning the relationships between the network entities and their time evolution. Since dynamical network inference is a complex task in general, scalable solutions are required. Therefore, it is necessary to evaluate the potential of online learning methods, such as kernel-based adaptive filters, high-dimensional set-theoretic algorithms, and other robust statistical estimation methods. Additional examples include Bayesian approaches in conjuncture with approximate inference methods, such as approximate message passing.

Although the convergence of AI/ML and communication networks is rapidly progressing, it is still in the early stage. As the various sensors, devices, applications, and systems connected in B5G networks will produce a variety of formats and sizes of data to be transmitted, it is extremely complex to standardize ML algorithms for B5G networks. No standard or baseline ML algorithm has been established and it is unclear

for the whole communication community which types of ML algorithms suit the B5G systems best. Recently, there have been some preliminary works on applying AL/ML to B5G networks in standards including ITU and 3GPP, as well as other study groups such as FuTURE, telecom infra project (TIP), and 5G PPP, as shown in Table I. ITU started a focus group on “Machine learning for future networks including 5G (ML5G)”1 by ITU-T Study Group 13 at its meeting in Geneva, 6–17 November 2017.

The focus group will draft technical reports and specifications for ML for future networks, including interfaces, network architectures, protocols, algorithms, and data formats. The three working groups are “Use cases, services and requirements”, “Data formats & ML technologies”, and “ML-aware network architecture”. 3GPP standards group developed a ML function that could allow 5G operators to monitor the status of a network slice or third-party application performance on “Zero Touch & Carrier Automation Congress”2 in Madrid, 22 March 2018. The network data analytics function (NWDAF) forms a part of the 3GPP’s 5G standardization efforts and could become a central point for analytics in the 5G core network. Note that the NWDAF is still in the “early stages” of standardization but could become “an interesting place for innovation”. A white paper named “Wireless big data for smart 5G”3 was published on Future forum in November 2017. It proposed the concept of “smart 5G” and believed that 5G network needs to embrace new and cutting-edge technologies such as wireless big data and AI to efficiently boost both spectrum efficiency and energy efficiency, improve the user experience, and reduce the cost. TIP launched a project group “AI and applied machine learning”4 in November 2017.

It will apply AI and ML to network planning, operations, and customer behavior identification to optimize service experience and increase automation. The objective is to define and share reusable, proven practices, models and technical requirements for applying AI and ML to reduce the cost of planning and operating telecommunications networks, understand and leverage customer behavior, and optimize service quality for an improved experience. 5G PPP also launched its efforts on combining AI with wireless communications, such as CogNet 5 . It aims to build an intelligent system of insights and action for 5G network

management. These developments in standards and study groups aim to use AI for physical layer and network management, which will greatly boost the performance of wireless networks.

Machine learning was born from pattern recognition and it is essentially based on the premise that machines should be endowed with artificial intelligence that enables them to learn from previous computations and adapt to their environment through experience . Due to growing volumes of generated data – across critical infrastructure, communication networks, and smart cities – and the need for intelligent data analytics, the use of machine learning algorithms has become ubiquitous across many sectors such as financial services, government, health care, technology, marketing, and entertainment. Using machine learning algorithms to build models that uncover connections and predict dynamic system or human behavior, system operators can make intelligent decisions without human intervention. For example, using machine learning enables a system to grasp the entire knowledge of social relationships between individuals and can recognize individuals' speech, face, and writing. Similarly, in a wireless system such as the IoT, machine learning tools can be used for big data analytics and edge intelligence. Machine learning tasks often depend on the nature of their training data. In machine learning, training is the process that teaches the machining learning framework to achieve a specific goal, such as for speech recognition. In other words, training enables the machine learning framework to discover potentially relationships between the input data and output data of this machining learning framework. There exists, in general, four key classes of learning approaches [66]: a) supervised learning, b) unsupervised learning, c) semi-supervised learning, and d) reinforcement learning. Supervised learning algorithms are trained using labeled data. When dealing with labeled data, both the input data and its desired output data are known to the system. Supervised learning is commonly used in applications that have enough historical data. In contrast, training 8 of unsupervised learning tasks is done without labeled data. The goal of unsupervised learning is to explore the data and infer some structure directly from the unlabeled data. Semi-supervised learning is used for the same applications as supervised learning but it uses both labeled and unlabeled data for training. This type of learning

can be used with methods such as classification, regression and prediction. Semi-supervised learning is useful when the cost of a fully labeled training process is relatively high. In contrast to the previously discussed learning methods that need to be trained with historical data, reinforcement learning (RL) is trained by the data from implementation. The goal of RL is to learn an environment and find the best strategies for a given agent, in different environments. RL algorithms are used for robotics, gaming, and navigation [67]. To perform these learning tasks, several frameworks have been developed. Among those frameworks, artificial neural networks (ANNs) [60] constitute one of the most important pillars of machine learning, as they are able to mimic human intelligence, to model complex relationships between inputs and outputs, to find patterns in data, or to extract the statistical structure in an unknown joint probability distribution from the observed data. ANNs are inspired by the structure and functional aspects of biological neural networks, that can learn from observational complicated or imprecise data. ANNs process information in a manner that is analogous to the human brain. A given ANN is composed of a large number of highly interconnected processing elements working in parallel to solve a specific problem. ANNs can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. An ANN can create its own organisation or representation of the information it receives during learning time. Moreover, an ANN can be used in a self-organizing manner to learn how to perform tasks based on the data given for training or initial experience. Within the context of wireless communications, as will be clearer from the latter sections, ANNs can be used to investigate and predict network and user behavior so as to provide users' information for solving diverse wireless networking problems such as cell association, spectrum management, computational resource allocation, and cached content replacement. Moreover, recent developments of smart devices and mobile applications have significantly increased the level at which human users interact with mobile systems. A trained ANN can be thought of as an "expert" in dealing with human-related data.

In a traditional ANN, it is assumed that all inputs are independent from each other or all outputs are independent from each other. However, for

many tasks, the inputs (outputs) are related. For example, for mobility pattern prediction, the input data that is the users' locations are actually related. To this end, recurrent neural networks , which are ANN architectures that allow neuron connections from a neuron in one layer to neurons in previous layers, have been introduced. an RNN can be used to recognize an individual person's speech when they pronounce only one word at each step. Clearly, this task cannot be done in one step without combining different words from different steps. Another application example for RNN is mobility prediction.

An RNN can be used to predict the mobility patterns of certain vehicles. These patterns are related to the historical locations that the vehicles have been visited. This task also cannot be done in one step without combing historical locations from previous steps. Therefore, ANNs whose output depends only on the current input, such as FNNs, cannot perform tasks such as speech recognition. RNNs can also be seen as an ANN that have a "memory", which allows RNNs to store historical information. Thus far, all of the discussed ANNs, including FNN, RNN, and SNN, have assumed a single hidden layer. Such an architecture is typically referred to as a shallow neural network. In contrast, a deep neural network (DNN) is an ANN with multiple hidden layers between the input and output layers Therefore, a DNN models high-level abstractions in data through multiple nonlinear transformations and thus learning multiple levels of representation and abstraction. Several types of DNNs exist such as deep convolutional networks, deep RNNs, deep belief networks, deep feedforward networks, deep SNNs, deep Q-learning, deep ESN, deep residual network, and long-short term memory (LSTM). In fact, the reasons that have made the move from conventional, shallow ANNs, towards DNN possible and desirable are summarized as follows: • Improved computing capacity: The advances in hardware development and data processing capabilities are at the core of the recent renewed interest in developing DNNs. In particular, graphics processing units (GPUs), originally designed to support computer graphics in video games, have been recently used for speeding up the execution of machine learning algorithms.

This in turn has resulted in a faster and more parallelized computation thus decreasing the required processing time. 34 • Improved datasets:

The availability of a large amount of data has made the training of DNNs possible. • Improved training algorithms and network architectures: Deep network architectures and training algorithms have evolved over the years. For example, the use of rectified linear units (ReLU) instead of sigmoid or tanh has made training faster. The RelU activation function is defined as $f(x) = x$ for $x > 0$ and $f(x) = 0$ otherwise. It is that the ReLU activation function outperforms the sigmoidal one in DNNs and is six times faster than tanh for reaching the same training error. In fact, one major benefit of the ReLU activation function is the reduced likelihood of the gradient to vanish. Unlike the derivative of the sigmoid function which is always smaller than one, the gradient of the ReLU function is either 0 for input less than 0 or 1 for input greater than 0. Therefore, one can stack as much layers as needed without having the gradient neither vanish nor explode, thus yielding a faster learning. Another benefit of ReLUs is sparsity which arises when $x < 0$. Sigmoids on the other hand are always likely to generate some non-zero value resulting in dense representations. Sparse representations have been shown to be more beneficial than dense representations.

As opposed to shallow ANNs that have only one hidden layer, a DNN having multiple layers is more beneficial due to the following reasons: • Number of neurons: Generally, a shallow network would require a lot more neurons than a DNN for the same level of performance. In fact, the number of units in a shallow network grows exponentially with the complexity of the task. • Task learning: While shallow networks can be effective to solve small-scale problems, they can be ineffective when dealing with more complex problems such as image recognition. In fact, the main issue is that shallow networks are very good at memorization, but not so good at generalization. As such, DNNs are more suitable for many real-world tasks which often involve complex problems that are solved by decomposing the function that needs to be learned into a composition of several simpler functions thus making the learning process effective.

# Chapter - 8

# Risk Of Using Artificial Intelligence In Telecom

In this section we present a model for analysing the risks of using AI applications in the telecom sector. That is to say, the model provides a framework for establishing a qualitative level of risk based on an application's specific characteristics. On the basis of this assessment, the supervisor can determine whether the risk is acceptable, or whether mitigation measures should be taken. When assessing the risks of AI in telecom infrastructures, we distinguish the systemic level (risk that a telecom infrastructure works as a whole) and the application level (risk with an individual AI application within a specific part of the infrastructure). Figure 6is the risk model developed for this study. At the top is an outline of the systemic level: the people, external factors and applications (including AI) that can cause risk events, which (ultimately) have a negative impact, causing companies and citizens to lose faith in telecom infrastructure and its applications. Our study focuses specifically on AI applications. At the systemic level, it is about embedding these AI applications. At the application level, we examine the relationship between these applications' characteristics and the likelihood and impact of risk events.

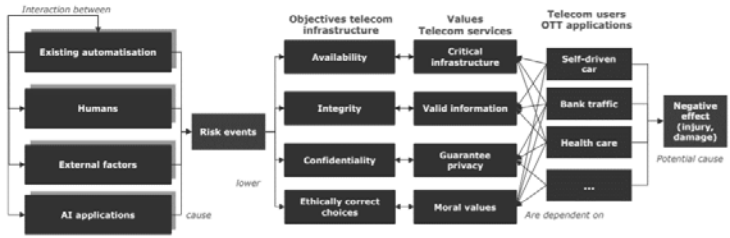
AI-to epassing Existing automation Risk events Negative effect (injury, damage) Humans External factors AI applications Objectives of telecom infrastructure Values of telecom service Telecom user OTT applications System level Application level Risk level Probability Effect Autonomy Predictability Damage Correlation with other events x + Correlaton with other effects No. of users / applications affected x Risk events from AI applications Risk mitigation (with AI) Characteristics of AI applications 26 Dialogic innovation ● interaction definition for the telecom sector. It

is even questionable whether risks can be objectively assessed, or that there are necessarily associated subjective assumptions and choices.

To some extent risks can be assessed in advance. This does not mean that such an assessment is always correct, complete and objective, or even possible. It is important to realize that not all risks are knowable.

To illustrate: an aircraft manufacturer could base the risk of crashing on the failure probability of individual components and the impact of that failure. However, the aircraft manufacturer must also take into account the simultaneous failure of components. These risks are knowable but can of course be “missed”. In addition, there are risks that the aircraft manufacturer cannot assess: retrospectively, a component could appear to have been sensitive to radiation, yet the aircraft manufacturer had not identified or been able to logically deduce this aspect. A final category, the known unknowable risks, involves the risks which people know can exist, but their precise extent cannot be estimated.

In de context of this research, importantly the modelling can only involve knowable risks. Knowable Unknowable Unknown Unknown knowable risks Unknown unknowable risks Known Known knowable risks Known unknowable risks.The four risk categories In this study we apply the definition of risk as stated : A (knowable) risk involves a potential risk event (scenario), the probability this will occur and the (negative) effect of this event. The higher the product probability and effect, the greater the risk.  Depending on the method, another weighting or multiplication is used, Lowering the probability and/or the impact are the logical ways to mitigate the risk. Conversely, the risk can be accepted if the negative event is highly unlikely, and/or if the negative effects are small or acceptable.



Social risks Telecom infrastructures play an important social role and are considered vital. More and more services are being delivered digitally, and have thus become dependent on a wellfunctioning, reliable and always available telecom infrastructure. Users therefore have certain expectations when using telecom networks. Failing to meet these expectations can have negative consequences. We now look at which social objectives a telecom network fulfils and how AI can influence them. From the perspective of the entire telecom system, we should also consider the societal effects. If applications use telecom infrastructure and cannot work properly due to for example outages, society has to pay the costs. In mission-critical situations, there may even be injuries. One example is the 'emergency button' on all C2000 two-way radios used by the police and the fire brigade. If that button does not work, officers in an emergency cannot call their fellow officers in time and may become victims in a dangerous situation. So what are the relevant target parameters related to any risks in telecom infrastructures? Iwe see a telecom system model based on services consisting of a network of nodes and links, both linked to a set of risk events.

Our research looks specifically at the effects of telecom service outages as a result of these events. In Vriezekolk’s dissertation, Dialogic innovation ● interaction 27 along with outages, we see other telecom infrastructure objectives that should be included in the research analysis as discussed below.

Availability of networks Society depends more and more on the availability of telecom networks. As it is becoming such a critical infrastructure, telecom requires the highest possible availability. Applying AI can increase that availability, but also have a negative impact. When an AI system fails, it can sometimes shut down large sections of the network. If errors propagate from system A to system B, this can cause a chain reaction.

*Table 1 Potential weaknesses of AI applications regarding information security [37]*

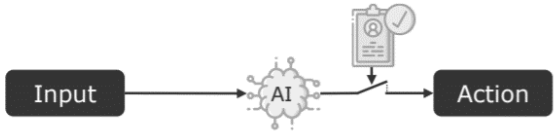
| Phase | Reliability | Integrity | Availability |
|---|---|---|---|
| Planning | • The (partial) use of existing models that contain malicious elements<br>• Backdoors and bugs in software frameworks for machine learning | | |
| Data collection | • Large amounts of data are required to train a model; this concentration of data is potentially risky. | • "Poisoning attack" whereby training data is manipulated to influence the ultimate result of the AI application (e.g. with hidden "trigger patterns"[8]) | • A bias occurs in the training data for a subset of cases, causing the ultimate AI application not to work properly for this subset |
| Training | • Training is often conducted in a shared (cloud) infrastructure, making it more difficult to guarantee confidentiality. | • Training in a shared (cloud) infrastructure means there is a (greater) possibility of sabotage occurring. | |
| Testing & evaluation | | • Manipulation of the test set can introduce a bias (in the feedback loop to training). | |
| Operation | • The model can contain 'hidden' information on sources (e.g. if a cell only contains one person), which can expose the model.<br>• Backdoors and bugs in underlying (cloud) infrastructure can endanger reliability. | • An attacker can manipulate weights in a model (thereby introducing 'trigger patterns' and affecting outcomes) without this being detected.<br>• Backdoors and bugs in underlying infrastructure can be inputs for sabotage.<br>• Adversarial attacks. | • Problems found in an AI system are difficult to correct without retraining; the turnaround time and thereby period of unavailability can be unacceptably high. |

Example: Chain reaction A mobile network applies "power management" procedures based on AI, determining which frequency bands are used in a base station. [34] If there are not many users, the number of bands is reduced to save energy. If it transpires that there have been no users in the surrounding areas for a longer period, the model can disable the base station entirely.

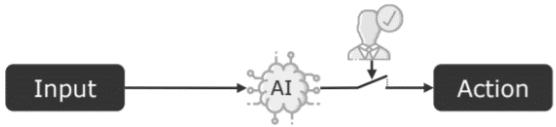
Consequently, a system to automatically determine "neighbour relations" (pairs of base stations between which a terminal can move in the network) fails. It seems as if there is less traffic for other base stations. This disables more base stations and propagates the failure throughout the network. Integrity of information Integrity is all about the accuracy and reliability of information.

AI can have a negative impact on some areas of application. In its informing role, AI can compromise the integrity of information. An AI system may be able to transform noise from another system into incorrect information.

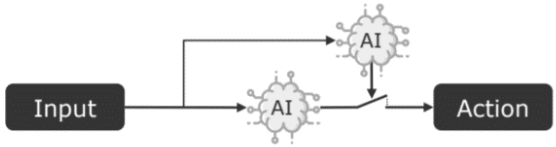
- In a rule-constrained closed loop scenario, an AI system can perform direct actions, but is restricted by certain "hard" rules. Breaking the rules results directly in the system being disabled or failing to perform the action. An example is autonomous vehicles, which are often equipped with various 'fail safe' rules that ensure a car makes an emergency stop in unsafe situations.




- In a **human-in-the-loop** scenario, AI can perform actions directly, but a human can stop or adjust these actions if necessary. An example is autonomous vehicles where people have to keep their hands on the steering wheel.




- In an **AI-in-the-loop** scenario, one or more additional AI systems monitor an AI system that performs actions. The controlling AI model can view the original inputs and the AI's decision, and assess whether this decision is correct.




Example: AI-generated information ensures obfuscation A predictive maintenance system uses moisture sensors in the ground to predict when cables will corrode. However, a broken sensor keeps on delivering the same data. The AI model, which is not prepared for the "broken sensor" situation, interprets this data as if the sensor is working.

As a result, a corroded cable is spotted too late. One solution would be to run the sensors redundantly or include more (different) information in the model. Reliability of data Telecom providers are dealing with large amounts of sensitive information; not only the information that customers exchange over the network, but also (meta)data about customers and this traffic. AI applications in telecom infrastructures can be (partly) trained based on this sensitive data. It is conceivable that a malicious person can trace sensitive data from these AI systems.

Dialogic innovation ● interaction Example: trace personal data from AI An AI system detects fraud on the basis of subscribers' characteristics. The system is continuously trained using customer data and information

on fraud cases. It is possible that one characteristic (or specific combination of characteristics) only appears for one subscriber. Everyone with access to the fraud detection system can now trace this particular person as fraudster by entering the data.

The system has to be built in such a way that the number of persons who can be traced (the cell size) based on outcomes is always above a certain lower limit. Potentially unethical choices in telecom infrastructures When choices have to be made in a telecom network, for example about which traffic has priority or where certain capacity is used, some social values may be inadequate or not observed. For example, if emergency services must always be able to use a certain minimum capacity in a mobile network, then this requirement should not be undermined by the application of a particular AI algorithm.

Unlike the aforementioned impact, this is an effect at the societal level, where the objective is not a specific application (including provision of the required connectivity) but the socially desirable (ethical) outcome. In some cases, a decision can be made on the basis of data that should not be used for this purpose or is at least debatable. Several examples are known, such as applications that use the battery level of a smartphone to determine the user's creditworthiness.

[Example: Decisions based on undesirable information AI that has access to all the data available to a telecom operator makes integral decisions based on that data. Because AI itself models the relationships between in and output, it is not known in advance how that information will be used for decision-making. Can AI for example give calls to customer service lower or higher priority based on the fact a customer has not previously reported a complaint to customer services? The same risk applies when telecom data outside the telecom sector is used in AI applications. Example: Pre-emptive or prioritising? In a disaster scenario, it is crucial that emergency services can always communicate. This can be arranged in different ways in a network. For example, capacity can be permanently reserved for emergency services (a type of "escape lane"), or the capacity of users with lower priority is reduced the moment emergency services need it.

In the past, various techniques proved to have individual advantages and disadvantages in different scenarios. A person or system that designs and manages a telecom network must weigh up these pros and cons in a normative framework. An AI system may not be able to make its own appropriate normative decisions.

Risk propogation in the telecom chain Risks should be considered not only individually, but also in relation to each other: what happens when two events occur at the same time? What happens if one event is the result of another event.

Figure schematically how AI applications, people, external factors, and existing automation (whether or not interactive) can lead to risk events. These events negatively impact telecom infrastructure's objectives, endanger the telecom services' values, and negative effects may arise due to the malfunctioning of the individual applications.

Here we focus on the violation of telecom infrastructures' objectives. Dialogic innovation ● interaction 29 Figure . How AI applications cause risk events and ultimately have a negative societal impact Deploying AI applications in telecom infrastructures can make a difference to the overall extent of risk at a systemic level. Any risk that already existed and has not increased or been reduced by applying AI is not considered in this study. Differences can arise in the following ways:

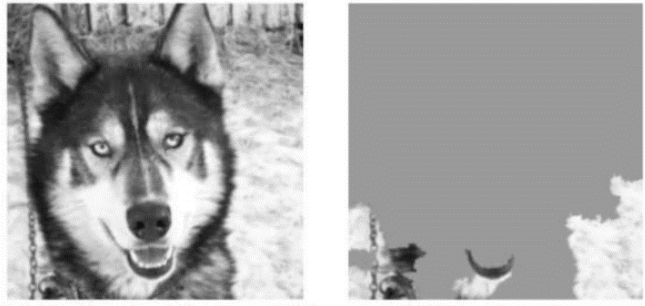



*Figure 9 AI's use of information to classify animals [39]*

The lack of transparency in AI models makes it easier for a malicious person (within or outside the organization) to perform manipulations and causes these to remain undetected for longer. In this way an attacker with access to a model can change weights without this being noticed directly, but which create a trigger *pattern* in the system.

- Applying AI. We discuss the risks at application level in paragraph.
- Interaction between AI application and other systems. We will also discuss this in paragraph 3.correlated to probability and/or effect.
- Replacing people with AI. Having AI perform a task incurs risks, and these can be both higher or lower than when a person performs that task. This study does not chart the risks of human action in telecom infrastructures. However, the model presented in paragraph can help to determine the risks of the replacement AI application, and thus inform the decision whether to deploy an AI application that replaces humans.
- Cyber (in) security of AI applications. Of course, AI applications are also subject to cyber threats and associated security risks, which we discuss in paragraph •

Applying AI to mitigate risks. In contrast, this concerns AI applications specifically geared to mitigating risks. Obviously, the positive effects have to outweigh any potential new risks. We discuss this aspect in paragraph Cyber (in)security of AI applications AI applications are information systems and are therefore subject to all potential cyber threats (breaches of confidentiality, integrity and availability of information). Berghoff et al. provide an analysis of weaknesses broken down into the various phases of an AI application's lifecycle. This highlights the large number of risks that already existed for non-AIbased information systems in telecom infrastructure: information security is needed wherever we use data. The risks found by Berghoff et al. [37] apply to some extent in regular systems and to the decision-makers (and thereby deal with manipulated information).

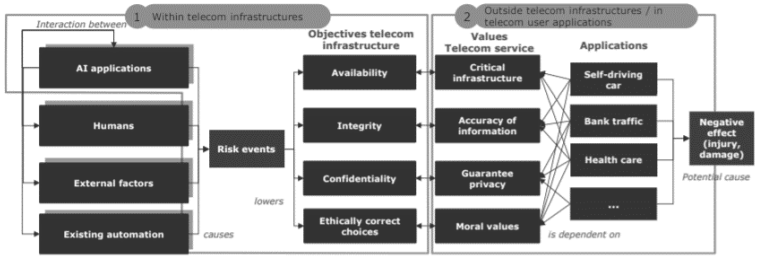
## 8.2 Mitigating risks based on AI:

AI applications in the telecom sector not only cause risks but are also used to mitigate risks. This can be done in a number of ways: • Anomaly detection. Based on small signals or a combination of signals, AI can detect a certain deviation earl(y)ier (e.g. a failing component). Thus, a relevant part can be replaced more quickly, reducing the risk of (later) outages. Another example is using AI-based firewalls that can recognize new forms of dangerous traffic without having previously observed

them. This lowers the level of risk because there is a reduced likelihood of risk

Unlike the use of AI for direct control applications in telecom infrastructure, the risks here are lower. If the system correctly observes certain things (“true positives”), the added value is high, whereas not observing things (“false negatives”) does not lower the risk level compared to the situation without AI. Moreover, incorrectly observing things that are not harmful (false positives) can cause problems, although in many cases these will be less than the added value of the “true positives”. • Root cause analysis. In a fault situation or report of failure, AI can be used to determine the cause of failure more quickly. This enables more effective and faster action. The level of risk becomes lower because the negative effect is minimalised. 8 An infrequent combination of input parameters that remains untested in testing/validation, and forces a certain outcome in the AI model. Dialogic innovation ● interaction 31 Simulation. If large sections of a telecom infrastructure are controlled by AI, it is easier to simulate how the system behaves in the event of a calamity. For example, using a copy of the steering model, you can test what happens when large parts of the network fail or for example when misinformation is entered. Such a 'fire drill' can in principle even take place continually. This type of simulation is much more complicated to achieve for an organization where systems work together with people. When AI is used for risk mitigation, a consideration will have to be made as to whether the deployment of AI caused a net increase or reduction in risk level, and/or the maximum level of risk is not exceeded. Example: send technicians to the right location In a telecom network, many network functions are interdependent; the underlying cause of an error may be due to an error occurring in a completely different system. Determining the underlying cause is sometimes difficult, especially (with outage) when it needs to be done quickly. AI can speed up this process by assessing the location of the root cause based on network information. The AI could, of course, be wrong and thus actually delay the recovery process. However, to assess the AI’s effectiveness, a large number of simulations can simply be carried out beforehand, to check whether the AI draws the correct conclusion. During a calamity, AI could also make multiple assessments, whereby data from another subsystem is

continually removed, and checks are made whether the same conclusion is still valid.




A non-transparent system increases the risk of adversarial attacks. [40] If the AI is nontransparent, characteristics that are not robust (such as snow in the husky-wolf example) may be used for classification. If it is not known which precise characteristics are being used, a malicious person can manipulate the non-robust characteristics without the system developer being aware of this. There are also conceivable scenarios where transparent AI is not desirable. If a security system has precisely known rules, an attacker can search for holes and the adversarial attack is easier to carry out. In a continuously learning non-transparent system, the systematic search for a leak is more difficult, but of course the system is not by definition safer.

Non-linearity AI models, depending on their implementation, can exhibit strong non-linear behaviour. On the one hand, this ensures that these models can form very powerful representations. On the other hand, such behaviour makes it more difficult or impossible to assess the likelihood of negative effects. Figure 10 is an example of a model where an outcome is assessed on the basis of two parameters (x and y, shown as red and green; this could be a classifier that categorizes network traffic based on two properties like 'good' or 'bad'). As the image demonstrates, the transitions at certain points are sharper than at others.

Example of a non-linear model with two parameters and ‘decision boundaries’ for classification in two categories (source: Dialogic). Researchers recently discovered an example of nonlinear behaviour in practice, namely in an algorithm for self-driving Teslas that recognizes speed signs. By extending the middle leg of the number "3" with a few

centimetres of tape on a speed sign marked "35", the car suddenly identified the number on the board as "80". [41] Figure 11shows this schematically. An AI model's assessment ("probability of it being an 80 sign") increases non-linearity as a result of a very specific characteristic. Figure 11 Non-linear activation functions in AI models lead to non-linear behaviour in the model (source: [41], visualisation: Dialogic) Non-linearity has a greater impact on the likelihood of negative effects if the data the model uses can be manipulated by third parties (as in the example with the speed sign), and if the data is not properly validated and certain input values fall beyond the limits to which the model was trained.

- 1 0 1 1 0 1 Input parameter X Input parameter Y 35 35 P(80)=1 0 38 Dialogic innovation ● interaction The predictability of AI models has a direct impact on the amount of negative effects occurring as well as the extent to which these can be determined with certainty. The greater the lack of transparency, the greater the risk (the model's operation is difficult to control) and there is the possibility of non-linear behaviour.

The risk is greatest if the data can be manipulated or is insufficiently controlled. There are various methods that increase the predictability of AI systems. One method is to create a simulation that can test the AI system before it is applied. For a classification model with two parameters (x,y) as input that can assume values between -1 and 1, it is easy to explore the entire input-output space. By placing each input parameter on an axis and trying out the potential values, we can determine the decision boundary (the moment when the model chooses between A and B) of a classification model. Because of the large parameter space in which AI systems make decisions, it is difficult to explore the entire input space. [37] This soon makes it very complicated to interpret the decision boundaries in a high dimensionality with sometimes more than 1000 input variables.

New situations An AI model is often trained with large amounts of data collected in the past. Thus, an AI model learns which outputs are suitable for which combinations of inputs. Because this learning is done on the basis of historical data, the AI model assumes that new, previously unseen combinations of inputs, can be predicted based on earlier combinations. In some situations, this assumption may be incorrect. For

example, it has been shown that historical stock prices can be perfectly predicted based on AI models, but these models are anything but capable of predicting future stock prices correctly. The adage past results do not guarantee future performance therefore also applies to using AI.

AI cannot cope well with new situations because it lacks an 'understanding' of the underlying relationships. AI only looks at input and output, and the underlying relationships are nothing more than a 'black box'. The likelihood of risk events increases in scenarios where new situations can arise. Because of the above, it is important that the limits placed on inputs to an AI model are known and observed. For example, a model could be trained and tested within a certain range of a particular input variable. Technically speaking, such a model will be able to generate outcomes beyond this range . However, these outcomes might bear no relation to reality, because the model has never been trained in them: the model 'extrapolates' reality but in a purely mathematical way, without it being established as valid. AI models have limitations when it comes to input data.

If the data entered lies outside the validated range, the outcomes may also be invalid. It is important that these boundaries are known and enforced in the use of AI. Otherwise, the likelihood of risky events (due to incorrect outcomes) increases.

Example of a model trained in a certain input range, that will generate output (the colours in the chart) for values beyond this range Correlation It is conceivable that several events have to take place first before a negative effect occurs. For example, many systems in aircraft are duplicated. In principle, negative effects only occur when both systems fail. However, the events that (together) have a detrimental effect may be correlated. In the aircraft example, it is feasible that both systems have the same defect or suffer from common cause failure. If events are related, we call this a correlation between the events (regardless of the cause). In the context of AI applications in the telecom sector, we see that a correlation of events can impact the likelihood of negative effects in two ways: • The output of one AI system is used as input by another. A fault in an earlier system can thus lead to a fault in a later system, via all the mechanisms described in this paragraph (e.g. invalid input data). An AI system’s output is also used as input for the same system, or the

systems are otherwise linked. 12 For the same reasons as above, this can lead to an escalation of incorrect outcomes.

an example outlining a situation where several AI “agents" operate and learn autonomously, but share observations. 0 0 1 1 0 -1 Model not trained/tested for values y < 0 Input parameter X Input parameter Y Input AI Output AI Output AI Output 40 Dialogic innovation ● interaction In a telecom network, a correlation scenario might be: a base station in a mobile network incorrectly stipulates that the radio signal must be amplified in a certain direction. A second basic signal measures an adjacent signal and adjusts its own configuration accordingly, which results in a similar error, and this is detected by the next base station. The error then infiltrates like an oil slick through the network. Correlation of events can increase the likelihood of negative effects.

The highly linked systems in telecom networks mean that when AI applications use each other's or their own output as input, the probability of correlation is highest. 3.2.3 Effect Looking at the effects of risk events arising from AI applications, we observe two determining factors: damage (the severity of the effect) and scope (the scope of the effect). In addition, we see that effects can be correlated; in other words, they can strengthen each other if they occur simultaneously. Damage The potential damage that AI can cause in a risk event is related to the algorithm’s action framework (i.e. humans, who would make the wrong decision based on AI advice) − the more important the decisions, the greater the risk. A larger number of different action options means that evaluating them could also be complicated for an algorithm supervisor.

The potential damage is greater if a human cannot (timely) intervene or if the algorithm's decision scope is not otherwise restricted. In this context, all the previous considerations regarding working autonomously (p. 33 apply. The more influential the (indirect) decisions of an AI application, the greater the negative effects in a risk event. Where an AI application acts autonomously, the negative effects are in some cases greater. Scope In addition to an AI application’s action framework, the scope of AI actions is significant.

In a telecom network, the scope can convey the number of (potentially) affected users or geographical areas. A telecom network has different

'layers' (such as access, transmission and core levels) where the scope is constantly expanding. Regarding the scope of an AI application in a telecom network, we see the following gradations: • Completely isolated. The algorithm makes choices that have an impact in a tightly defined environment. The AI outcomes have no impact whatsoever on other systems within the telecom infrastructure. An example is an algorithm that optimizes beamforming in a mast or improves noise reduction in a bundle of VDSL lines. A wrong outcome only impacts the connections in question. The applications are generally highly decentralised.

The scope is limited to (1) a single or small group of users, (2) a geographically strictly defined area, and/or (3) only the access part of the network. Input AI Output Dialogic innovation ● interaction 41 • Partially isolated. An algorithm's action framework is well defined, but there are ways an incorrect decision can impact other systems. This occurs, for example, if an algorithm output has a measurable effect on another system. Yet another conceivable route is that the failure of an AI system leads to surpassing security limits (e.g. a residual-current circuit breaker or fuse) that cause other systems to fail. The scope is limited, but is available to a larger group of users, larger geographic area, and/or more than just the access part of the network. • Not isolated. These are systems designed to control other systems. An error in the steering system has a direct impact on the functioning of the controlled systems.

The scope is potentially the entire network, all users, and the entire geographic coverage area. A technique that deserves special attention is edge computing, whereby intelligence (be it application-specific, and possibly based on AI) is applied to the periphery of the network. Although these applications' sphere of influence is local, there is a risk of influencing other applications that use the same infrastructure. In AI applications decentralised at the local level (and risks not correlated with each other), there are generally smaller negative effects on risk events than with central AI applications designed to control other systems.

Correlation Earlier we discussed that the correlated probabilities of risk events can lead to new (or a higher than expected probability for existing) risks. Correlation can also increase risks regarding effect. An analogy is securing a building from burglary: if the alarm is not switched on, there is no immediate increased risk of damage from break-in; after

all, the door is locked. If only the door is not locked, there is also no immediate increased risk (after all, the alarm still works). However, if both the alarm is not turned on and the door is not locked, the risk is much greater than the sum of both risks: a burglar can now enter without any problems, and there is damage. Domino effect If systems are connected and decisions in one system affect another system, there is a risk of a “domino effect”: a system error causes an error in the next system. Such a mechanism was at the root of the “flash crash” on Wall Street in 2010.

One algorithm detected erroneous input as an anomaly and decided to sell securities. Other algorithms saw this act as deviant and acted in the same way, resulting in share prices ultimately collapsing and trading having to be shut down. [42] The rapid actions of the algorithms and the fact that it was not known that the algorithms contained “anomaly detection” mechanisms, meant that share prices slumped very quickly. It is of course equally possible that human stockbrokers would be susceptible to the same thing: they can panic, with ultimately the same effect. Redundancy and variation Redundancy is one way of mitigating risks.

By duplicating elements, the failure of one element can be absorbed by the other. In addition, the output from the two elements can be compared and when a difference arises, this is noticed (works best if the elements are completely different implementations of the same function). Redundancy is often installed in telecom networks; for example, networks are set up in rings, so that disconnection does not lead to a complete loss of connectivity between locations. One concept associated with redundancy is variation. Introducing redundancy to mitigate risks is only effective if the failure of the redundant elements is not mutually correlated.

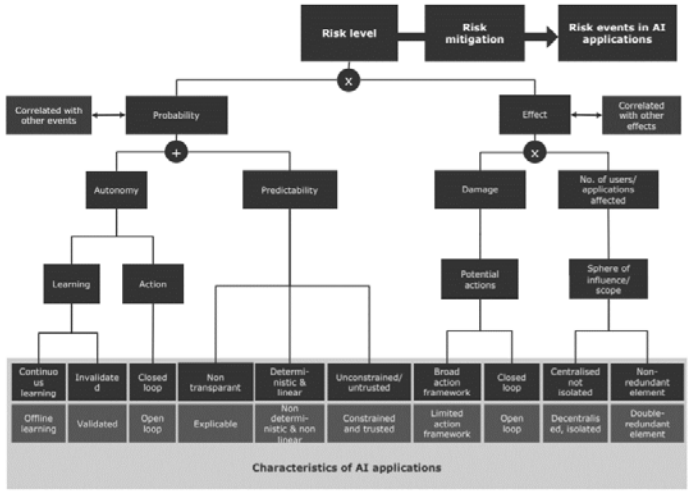
Two 42 Dialogic innovation ● interaction AI systems that are redundant from each other will − if they are otherwise exactly the same – make precisely the same error given the same input; in that case, in practice there is no reduced risk at all from redundancy. This can be solved by introducing variation. The two redundant AI applications are two different deployments (completely separate implementations, or perhaps an older version).13 There is therefore less chance that both systems

encounter an error at the same time. The negative effects of a risk event are smaller with an AI application acting in a redundant part of a telecom infrastructure, as long as there is no correlation between preventing risk events in multiple redundant setups.

## 8.3 Determining risk in AI Telecom:

As explained earlier, the actual risks of applying AI in telecom infrastructures can only be determined by analysing them at the systemic level. Not only AI applications in isolation, but also the interaction between AI applications and other systems have an impact on the occurrence of risk events. The resulting negative effects are strongly linked to the ultimate use of the telecom infrastructure. It is beyond the scope of this research, and in our view not possible, to create a fully comprehensive risk model, without looking at specific applications and situations.

That said, it does make sense to look at the characteristics of AI applications and their direct impact. We call this the application level. Below Diagram presents the model for assessing the additional risks incurred with individual applications of AI in telecom infrastructures. As discussed, the level of risk depends heavily on the characteristics of the AI application, which (indirectly) determine both the probability and the impact of risk events. Policies could be implemented for the relevant characteristics of AI applications. Risk mitigation by the operator can reduce the risk level of an application to an acceptable level (for the operator and society). In this area too, policy can be implemented. For a supervisor, this poses a key policy question: what level of risk is acceptable to society, and what mitigation measures should operators take? Scoring risk aspects at application level While the exact weighting of aspects in the risk model may be subject to discussion, based on our research (in particular the literature and discussions with experts), we provide the first steps for a scoring model as shown in Below Figure.


Risk level
Risk mitigation
Risk events in AI applications
X
Correlated with other events
Probability
Effect
Correlated with other effects
+
X
Autonomy
Predictability
Damage
No. of users/ applications affected
Learning
Action
Potential actions
Sphere of influence/ scope
Continuous learning
Invalidated
Closed loop
Non transparant
Determi-nistic & linear
Unconstrained/ untrusted
Broad action framework
Closed loop
Centralised not isolated
Non-redundant element
Offline learning
Validated
Open loop
Explicable
Non determi-nistic & non linear
Constrained and trusted
Limited action framework
Open loop
Decentralised, isolated
Double-redundant element
Characteristics of AI applications

# Chapter - 9

# Artificial Intelligence Telecom Operators Applications

## 9.1 Status and Trends in AI Technology:

The advancement of key algorithms, such as the deep learning, the knowledge graph, the Natural Language Processing (NLP), etc., the arrival of big data era, the increased computing power and the expansion of application scenarios, all have a profound impact on the development of the AI technology. This section firstly introduces the status of the AI technology.

### Data

Data is the cornerstone for the AI development. Recently progress of the AI technology mainly benefits from the large data base. Massive data provide raw materials for training the AI models. However, massive data cannot directly drive AI applications. It needs to be processed to become AI data sets. At present, public AI data sets, which are mostly constructed by academic and research institutions, are constantly enriched and their quality is constantly improving. Some AI data sets are as follows.

| Type | Data Set Name | Explanation |
|---|---|---|
| NLP | WikiText | Wikipedia corpus |
| | SQuAD | Stanford University question and answer dataset |
| | Common Crawl | Petabytes of data collected since 2011 |
| | Billion Words | The common language modeling database |
| Speech Recognition | VoxForge | An accented corpus |
| | TIMIT | An acoustic-phonemic continuous speech corpus |
| | CHIME | A speech recognition dataset containing environmental noise |
| Machine Vision | SVHN | Google street view house number dataset |
| | ImageNet | Common image datasets based on WordNet |
| | Labeled Faces in the Wild | A facial region image dataset for face recognition training |

In addition, the AI data sets are closely integrated with industries, which are the core competitiveness of enterprises. Therefore, enterprises construct industrial AI datasets in a self-built way. The self-built AI data sets of enterprises have promoted the development of the data service industry. At present, the data service industry mainly includes the dataset construction, the data cleaning, the data annotation, and so on.

## Algorithm

The machine learning algorithm and the deep learning algorithm are two hotspots in AI. The development of the deep learning algorithm rapidly drives the maturity of the speech recognition, the machine vision, NLP and other technologies. The open source AI algorithm framework is a driving force to promote the development of the AI technology. It allows the public to use, copy and modify the source code. It has the characteristics of fast update and scalability. It can greatly reduce the cost of enterprises and customers. These frameworks are widely used by enterprises to accelerate the iteration and maturity of their own technology, and ultimately achieve the application of products. Some of the mainstream frameworks are as follows.

| Framework | Source | Programming Language | Brief Introduction |
|---|---|---|---|
| TensorFlow | Google | Python/C++/Go/... | An open source library of the neural network |
| Caffe | UC Berkeley | C++/Python | An open source framework for convolution neural networks |
| Paddlepaddle | Baidu | Python/C++ | An open source platform for deep learning |
| CNTK | Microsoft | C++ | A deep learning computational network toolkit |
| Torch | Facebook | Lua | An open source framework for machine learning algorithms |
| Keras | Google | Python | Modular neural network library APIs |
| Theano | University of Montreal | Python. | A deep learning library |
| DL4J | Skymind | Java/Scala | A distributed deep learning library |
| MXNet | DMLC community | C++/Python/R/.. | An open source deep learning library |

current general purpose chips in the next few years and to become the main force of AI chips. Brain-like chips are still at the stage of the laboratory research and development. Open source AI algorithm frameworks have become the focus of technology giants. Google, Amazon, Facebook, Baidu, Alibaba, Tencent and other companies are accelerating the deployment of AI algorithm platforms. At present, there are more than 40 AI frameworks in the world.

## Computing Power

The implementation of AI algorithms needs support of the strong computing power, especially the large-scale use of deep learning algorithms, which puts forward higher requirements for the computing power. In recent years, the development of new high performance AI chips has become the main driving force of the AI technology evolution. According to the technical framework, AI chips can be divided into general purpose chips (CPU, GPU, FPGA), semi-customized chips based on FPGA, fully customized ASIC chips, brain-like computing chips

(IBM TrueNorth). In addition, the main AI processors include DPU, BPU, NPU, EPU and other AI chips for different scenarios and functions. From the development stage of AI chips, CPU, GPU and FPGA are the main chips in the AI field. ASIC chips for neural network algorithms are being introduced by Intel, Google, NVIDIA and many start-ups, and it is expected to replace the

## Application Scenario

The industry generally believes that application scenario is the fourth element of AI, and also the core element of industrial applications. Next, the trends of the AI technology are introduced. The development of the AI technology has remarkable characteristics in the following aspects, which reflect the AI trends.

1) Open Source AI Platform to AI Industry Ecology An open source AI framework has made remarkable achievements in AI fields. It enables developers to use existing AI tools directly, reduce the secondary development, and promote the industry cooperation. The industrial giants have also realized that the establishment of an industrial ecology through the open source technology is an important means to seize the industrial commanding heights. Through the open source technology platform, we can expand the scale of technologies, integrate technologies and applications, and effectively lay out the whole AI industry chain. Leading enterprises such as Google and Baidu have laid out the open source AI ecosystem one after another. In the future, more software and hardware enterprises will participate in the open source ecosystem.

2) ANI to AGI At present, AI can only deal with a single field of problems, such as the picture, the character, the speech, and so on, which is still in the stage of ANI. Since various fields are interacting with each other, ANI with a wide range is needed with the development of science and technology. AGI can perform general intelligent behaviors. It can connect AI with human characteristics such as perception, knowledge, consciousness and intuition, reducing the dependence on knowledge of specific areas and improving the adaptability of processing tasks.

3) Perceptual Intelligence to Cognitive Intelligence The development of AI mainly includes the operational intelligence, the perceptual

intelligence and the cognitive intelligence, which is widely recognized by the industry. Presently AI is the perceptual intelligence, and machines have the perceptional abilities of vision, hearing and touch. In the future, AI advances to the era of the cognitive intelligence.

## 9.2 Status and Trends in AI:

Product Characteristics of AI products are as follows. At present, AI products mainly focus on a single scenario to provide services for users. The user experience of AI products in complex scenarios is not good. So, the user experience needs to be further improved. Further, AI products concentrate on areas of voice, image and text where deep learning algorithms are good at. AI products in other areas are not rich enough. Trends of AI products are summarized as follows. Intelligent products will support more single scenarios, and AI products of multi-scenario will gradually emerge. Improvement in the user experience will go ahead, such as the speech recognition accuracy and semantic understanding accuracy. The products for industry applications are gradually enriched since the demand for AI technology and products increases, including the fields of the industrial Internet, the manufacturing, the household, the finance, the education, the transportation, the security, the medical treatment and the logistics.

## 9.3 Status and Trends in AI Industry:

As the core driving force of the new round of industrial change, AI will bring about new technologies, products and industries. Meanwhile, it will trigger major changes in economic structure and achieve the overall improvement of social productivity. McKinsey & Company predicts that the global AI application market will reach 127 billion US dollars by 2025, and AI will be the breakthrough point for the development of many intelligent industries. According to the “Blue Book of World Artificial Intelligence Industry 2018” of CAICT, the total number of AI enterprises in the world was 4925 by June 2018. American has 2028 AI enterprises, ranking first in the world. China has 1011 AI enterprises, ranking second in the world. Then, it was followed by Britain, Canada and India. In 2017, the global AI investment and financing scale reached 39.5 billion US dollars. Chinese investment and financing scale reached

27.7 billion US dollars, accounting for 70% of the total. China has become the world's largest capital-absorbing country in AI field. Global AI enterprises mainly focus on the business (e.g., marketing and customer management), the medical health, and the financial fields. The AI technology is merging with the business of various industries, and AI will be the breakthrough point of many industries. The followings are some examples

### 1) AI + Medical

The application of AI technology in the field of medical and health care can significantly improve the efficiency of medical institutions and personnel.

### 2) AI + Finance

Finance is one of the most data-dependent industries. Integration of the AI technology and the financial industry will deeply reconstruct the ecological pattern of the current financial industry and make the financial services (e.g., the bank and the insurance) more humanized and intelligent.

### 3) AI + Education

The application of AI technology in education can help teachers pay more attention to students' characteristics and improve the quality of teaching. The intelligent education covers the industry chain of "the teaching, the learning, examinations, evaluation and management for teachers". It plays an important role in various sub-tracks, such as the kindergarten education, K12, the higher education, the vocational education, the online education, etc.

### 4) AI + Home

The application of AI technology in the field of the home makes the household life safer, more comfortable, energy-saving, efficient and convenient. In the future, the smart home will gradually achieve the adaptive learning and control functions to meet the individual needs of different families. From the perspective of the development process of the AI industry, AI is triggering the fourth industrial revolution. The following trends are emerging.

### Increment in AI Industry Scale

Statisticians predict that the global AI market will grow at an average annual rate of 50.7% in next 10 years. According to Chinese “New Generation of AI Development Plan”, the scale of the AI core industry in China will exceed 400 billion yuan by 2025, driving the scale of related industries to exceed 5 trillion yuan. By 2030, the scale of the AI core industry in China will exceed 1 trillion yuan, driving the scale of related industries to exceed 10 trillion yuan.

### Adaptability to multiple scenarios

The application fields of AI are mostly for one scenario, such as the face recognition, the video surveillance, the speech recognition, and so on. The coverage is limited, and the degree of industrialization needs to be improved. In the future, AI is adaptable to multiple and complex scenarios with the introduction of new AI products like that of the smart home and the intelligent logistics.

### Shortage of AI Talents

The gap of AI talents will be further expanded. The demand for AI talents will change from IT to AI. The shortage of AI talents won’t improve in next few years.

# Chapter - 10

# Ai + Telecom Operators

While AI is sweeping the world and promoting development of all industries, telecom operators are using AI to enhance the network intelligence, improve the user experience, and expand vertical industries.

## 10.1 Networks:

The Internet of Things (IoT), the Software Defined Network (SDN), the Network Function Virtualization (NFV) and 5G are the potential directions for the network evolution. However, the number of network devices and data in IoT are growing rapidly. The video, the Augmented Reality (AR), the Virtual Reality (VR) and other services causing large traffic are emerging. These lead to a great increase in the network equipment and traffic. Network architecture reconfiguration based on SDN/NFV/Cloud enjoys the flexibility, but it gives rise to management and control complexity in new dimensions. While 5G network brings great progress in performance and flexibility, its complexity also increases significantly. Integration of the AI technology and the telecom network provides potential solutions to the above problems. Specifically, the powerful capabilities of AI in aspects of analysis, judgment and prediction can make the network intelligent. For the current network, AI can empowers the network with capabilities of analysis, judgement and prediction, promoting the development of the network planning, the network construction, and the network operation and optimization. For the future network such as SDN/NF and 5G, AI provides training and inference capabilities in the infrastructure layer, the network and business layer, and the management and orchestration layer.

## 10.2 Services:

Some basic AI capabilities, like the speech recognition and the Natural Language Processing (NLP), are gradually used in various scenarios of services of telecom operators. In particular, the typical applications are the intelligent customer service and the smart home. In the smart home, telecom operators have launched virtual assistants and household products that have the capabilities of the intelligent control and interaction. In the intelligent customer service, virtual assistants and customer service robots have been able to replace much of the work done by customer service staff.

## 10.3 Industries as a general enabling technology:

AI can serve all industries so AI can help telecom operators to achieve the digital transformation to expand service capabilities and business channels for industries. Now, AI technologies, such as the computer vision, the speech and semantic recognition and NLP, have already been successful in commercial use. They can quickly integrate with the business capabilities of telecom operators to achieve composition of services of multiple industries to open up new market areas and to increase revenue. With the help of AI, telecom operators are no longer confined to services of the traditional network communication. They can expand their business areas to multiple vertical industries. On the one hand, telecom operators are improving their technological innovation ability and building an AI platform that integrates their own network with various industries. On the other hand, telecom operators are improving their business innovation ability, deeply cooperating with many manufacturers of the AI technology, and launching a number of services for vertical industries including the smart cities, the smart government, the smart agriculture, and so on.

# Chapter - 11

# Applications In Telecom Sector

## 11.1 China Mobile:

China Mobile Communications Corporation (CMCC) was established on April 20, 2000. It is the telecommunication operator with the largest network, the largest number of customers and the highest market capitalization in China. China Mobile mainly operates mobile voice, data, broadband, IP telephony and multimedia services.

1) Intelligent networks In 2018, China Mobile developed independently three products for network optimization and operation: the Autonomous Coverage Optimization System (ACOS), the Autonomous Parameter Optimization System (APOS) and AI for IT Operations (AIOps). ACOS based on deep learning can intelligently analyze cellular coverage and provide suggestions for network optimization. APOS supports optimization in complex network environment with sufficient AI algorithms. AIOps can provide operation functions such as failure predictions, device information statistics and unstructured data extraction. In 2018, China Mobile partnered with AT&T, Deutsche Telekom, NTT DoCoMo, and Orange to set up the Ohrand Alliance for promoting the development of open-source and intelligent network. On June 27, 2018, China Mobile collaborated with 12 telecom operators from all over the world such as AT&T, SKT&T, NTT to establish the O-RAN Alliance. The alliance is committed to introducing AI and SDN to wireless network.

2) Intelligent services Intelligent Customer Services In 2016, China Mobile launched an intelligent robot for customer service called “Yiwa”. “Yiwa” is an intelligent interactive system for customers, supporting both text and voice interaction. It has more than 200 million interactions monthly, which are equivalent to the workload of 1000 staff of the

customer service, saving more than 100 million yuan in labor costs. Smart Home In 2016, China Mobile created China Mobile Digital Home Alliance (CMDHA) with the smart home companies, promoting innovation of smart home products and developing home devices such as smart headphones and smart watches. In 2016, China Mobile released a protocol for smart home called “Andlink”. The protocol is to facilitate connections among multiple smart home devices.

3) Intelligent industries Platform On November 24, 2017, China Mobile launched an AI platform called “Jiu Tian”. “Jiu Tian” focuses on the market operations, networks, services and other application areas of telecom operators. It provides end-to-end AI application solutions for the vertical industry. The platform consists of three layers. The top layer is about the product application, which contains smart operation, smart connection, and smart service. The middle layer is the core ability, which includes speech and language, image and video, and structured data. The bottom layer is the deep learning platform based on GPU and other infrastructures.

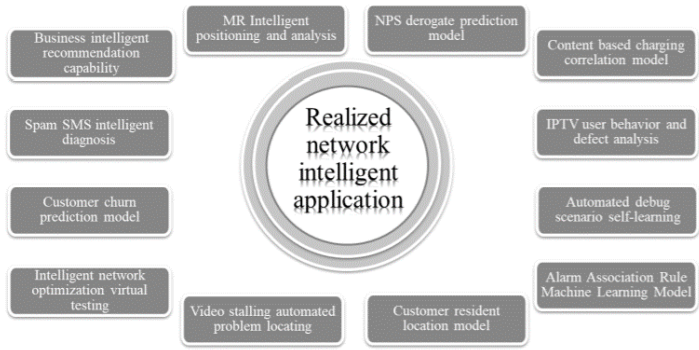
Intelligent Transportation In September 2019, China Mobile created an alliance with automobile manufacturers and colleges for research on auto-drive. China Mobile also released Chinese first test road for auto-drive cars. A smart vehicle terminal called “Helutong” was released one month later, it integrates voice recognition and interaction, ETC and other intelligent functions.

## 11.2 China Unicom:

China United Network Communications Corporation Limited (China Unicom) was officially established on January 6, 2009 by merging former China Netcom and former China Unicom. It is the only Chinese telecom operator listed on the stock exchanges of New York, Hong Kong, and Shanghai. It has been a Fortune 500 company for many years and was ranked at No. 273 in Fortune 500 in 2018. China Unicom operates a wide range of services, including fixed communication services, mobile communication services, domestic and international communication facilities services, the satellite International Private Lease (IPL) service, data communication services, network access

services, telecom value-added services, and system integration services related to information and communication.

Intelligent networks China Unicom has started researches and applications related to AI on the network planning, the network design, the network maintenance, the network optimization, the security, SDN/NFV, 5G, the edge computing and IoT. It is also planning for the network brain project. At present, China Unicom has implemented many intelligent network applications.




## CUBE-Net 2.0+

China Unicom announced the launch of CUBE-Net2.0+ network architecture to build a new generation of an AI enabled intelligent network at the 5G and network transformation conference in June 2018.

## AR Intelligent Operation and Maintenance System

China Unicom exhibited the “AR Intelligent Operation and Maintenance System” at the PT/EXPO China 2017 held in Beijing. The system runs through the whole work flow of frontline inspectors, including the precise intelligent detection, the remote maintenance and guidance by experts, the fault discovery for base stations, the worksheet upload, the transmission of the real scene, etc.

## Network Security Situation Awareness Analysis System

China Unicom Network Security Situation Awareness Analysis System is a key innovation achievement. The system uses the AI and big data technology to collect and compare logs of multiple security systems. It

fulfills the comprehensive analysis and unified presentation of multi-dimensional security situation of the existing network, and enables operators to grasp the security situation of the network.

## Origin of Network Alarm

China Unicom applies AI technology to trace the origin of alarm in IPRAN network, filter the alarm, obtain the alarm information worthy of attention, and form a more efficient alarm processing method.

## Network Information Platform

China Unicom launched a cloud platform “Tian Gong”. The platform builds an efficient IT ecosystem with the “platform + applications” mode that integrates open-source technologies and commercialization capability. China Unicom launched a research management platform “Tian Ti” based on agile development. The platform supports the entire procedures of project management including the demand analysis, the research & development, the test and the launch. China Unicom also launched a monitoring system “Tian Yan” to monitor platforms and applications in 7×24 hours.

## Network Information Plan:

China Unicom has stepped up overall planning to bolster the network information in the Management Support System (MSS), the Business Support System (BSS), the Operation Support System (OSS) and the Decision Support System (DSS). In MSS, China Unicom integrates the access to professional applications and office applications, applies clouds and micro services to MSS, designs and develops various management applications for the intelligent finance, manpower, e-mall, etc. In BSS, China Unicom seizes the opportunity of the mixed-ownership reform, and launches the “Operation 2.0” strategy to develop cross-border cooperation and the Internet operation in fields such as the new retail, the client applications and the billing system. In OSS, China Unicom focuses on the construction of the basic capabilities, open platforms and core applications.

It launches OSS 2.0 which contains seven core functions that are the data collection, the resource management, the electronic operation

maintenance, the intelligent monitoring, the customers service support, the mobile business assurance and the innovation platform. In 2018, China Unicom developed the Open Network Service (ONS) based on OSS 2.0, enhancing the operation support for innovative network and business such as SDN, 5G and NB-IoT.

In DSS, China Unicom launches a big data platform based on Oracle, Hadoop, Spark, Storm, etc., enhancing the capability of access, process, integration and standardization for massive offline and online data. The platform provides China Unicom with centralized, unified and visual data management and scheduling capability.

### Network Management System:

China Unicom launched a network management system based on AI. The system introduces machine learning algorithms to build a prediction model for network traffic flow, providing abnormal situation alarm and intelligent troubleshooting.

### Intelligent NFV Operation and Maintenance Platform:

China Unicom launched an intelligent NFV operation and maintenance platform based on Open Web SA (OWS). The platform contains the fault experience base and the fault location function to support the internal work and external business.

### Private Line Service:

China Unicom launched the high-quality private line service by applying network flow prediction algorithms. With the capability of big data and AI, the service is able to actively perceive and predict customers' demands.

### Customer Departure Forecast Algorithm:

China Unicom develops a departure forecast algorithm for government and enterprise customers based on Spark, the deep learning and other big data and AI technologies. The algorithm builds customers' characteristic portrait by analyzing habits of using the network to provide services adapted to the customer's needs.

### Net Promoter Score Prediction and Improvement:

Telecom operators introduce Net Promoter Score (NPS) to evaluate customers' satisfaction. China Unicom analyses characteristics of unsatisfied customers and build prediction model. This model help China Unicom find the reason why customers give low score.

### Intelligent Operation and Maintenance Platform:

The intelligent operation and maintenance platform developed by China Unicom uses AI analytical ability and intelligent choreographer technology to manage hidden troubles and faults in network elements. For network elements in the core layer, the platform detects and assesses the hidden troubles. For network elements in access layer, the platform fulfills the intelligent troubleshooting and automatic self-healing.

### Intelligent Services:

#### Smart Home:

China Unicom's smart home products based on the voice interaction and gesture interaction includes the smart speakers, the IPTV set-top boxes, the AR/VR/MR and other products. China Unicom and China Telecom lead the project of AI Devices Guidelines standard in GSMA TSG. China Unicom has launched smart home platform "Steward of Wo Jia" to fulfill the interactions among smart home terminals.

#### Online Customer Service:

China Unicom has launched the intelligent online customer service robot "Wobao" to solve various business problems in business hall and mobile phone business hall client. China Unicom has launched an Intelligent Voice Customer Service System, which uses AI technologies such as the speech recognition, the speech synthesis and NPL to fulfill voice dialogue between the intelligent system and customers and solve business problems for users.

#### Intelligent Call Center:

China Unicom introduced an intelligent voice outcall service system, which uses machine instead of human to fulfill automatic outcall function, reduced the cost of customer maintenance, and enhanced the

marketing ability of new business. China Unicom cooperates with Baidu, Ali and other AI enterprises to export intelligent call center cloud solutions to the whole industry, enhances customer perception and reduces enterprise operating costs.

### Intelligent industries:

Smart City China Unicom is the overall responsible unit of Xiong'an digital project. It provides smart city solution for Xiong'an and uses AI technology to perform the construction of the smart city infrastructure. China Unicom is building an intelligent digital infrastructure with characters of high speed and security, and an urban big data platform with the core of open and share. Meanwhile, it plans to build a city cloud brain which can enjoy the intelligent data analysis, and a new ecological system of a government-led intelligent city. On January 24, 2018, the standard project "Reference Architecture of Artificial Intelligence Service Exposure for Smart Sustainable Cities" led by China Unicom and FiberHome Technologies Group became the first AI project of ITU SG20.

### Intelligent Government Enterprises:

China Unicom actively introduces AI technology into "XueLiang Project". It combines the face recognition, the license plate comparison, the big data analysis, the comprehensive layout control and other technologies with the construction of a county, a town and a village to provide precautionary measure to citizens.

### Intelligent Transportation:

In June 2017, China Unicom cooperated with other companies to explore the integration of the intelligent driving and the communication technology. China Unicom demonstrated the application scheme of the cellular vehicle-to-everything (C-V2X) technology that supports multi-scene fusion through the real vehicle test at the National Intelligent Network United Automobile Test Base (Shanghai). At the Mobile World Congress (MWC) Shanghai June 2017, China Unicom cooperated with other companies to demonstrate the 5G ultra-long-distance intelligent driving for the first time in the industry.

### Intelligent Medical:

China Unicom launched telemedicine workstations and 5G intelligent respirator with Tencent, also launched a self-developed and pioneered "5G respirator medical networking clinical decision-making analysis system". China Unicom has cooperated with Tencent to launch cloud solutions for medical image application scenarios by using the image recognition and the deep learning technology to automatically recognize medical images such as CT and MRI of patients. It helps doctors to improve the diagnosis efficiency.

### Intelligent Environmental Protection:

China Unicom and Chinese Central Meteorological Station have built a "Smart Blue Sky" air pollution prevention and control platform. The platform integrates the desensitized communication data with the atmospheric environment data, achieves fine air pollution prevention and control, intellectualizes enterprise environmental protection monitoring, and helps "Green Winter Olympics" and "Smart Winter Olympics". China Unicom applies the computer vision technology to the intelligent river length solution to achieve intelligent video surveillance for rivers, reservoirs, sewage outlets and other key areas.

### Intelligent Education:

China Unicom and South China Normal University cooperated to set up the "Artificial Intelligence + Teachers' Ability Development Joint Laboratory". The two sides carried out relevant cooperative research and product development around evaluation of teachers' ability development, AI technology in education industry, platforms of the education industry, etc.

### Intelligent UAV:

In March 2018, China Unicom has completed the world's first 4G network based flight measurement and control test of a long-distance high-altitude industrial UAV. It successfully achieved the oversight flight of UAVs in highland and mountain areas by using the network of telecom operators. China Unicom, in conjunction with other companies, has launched 5G UAV intelligent security products. The face recognition technology is used to analyze monitoring pictures in real time. Combined

with geographic map and historical data in background database, the automatic identification of suspicious people is implemented and the monitoring efficiency is improved. Intelligent networked UAV low-altitude communication system is an integrated and intelligent low-altitude communication network aiming at solving the problems of difficult UAV supervision. This system combines the edge computing, the 5G network evolution, big data technology, etc., and can provide basic communication services and customized value-added network services for UAV.

## 11.3 China Telecom:

China Telecommunications Group Corporation Limited ("China Telecom") is an integrated information service provider, and is one of the listed companies of state-owned China telecom corporations. China Telecom provides wireline and mobile telecommunications services, Internet access services, information services and other value-added telecommunications services.

### Intelligent networks:

In 2016, China Telecom released the CTNet2025 network architecture white paper, starting the intelligent network reconstruction. In February 2017, China Telecom and HUAWEI established ENI, the first global intelligent network standard working group in ETSI. In April 2018, China Telecom participated in issuing the Network Application of Artificial Intelligence White Paper. It introduces firstly the definition, typical application scenarios and future network framework of intelligence network. In May 2018, China Telecom issued 5G technical white paper, becoming the first telecom operator to explain the overall strategy of 5G. The white paper states that the operation of 5G will be more intelligent by means of data-driven AI technologies.

### Intelligent services Smart Home:

China Telecom cooperates with intelligent terminal manufacturers to develop a smart speaker (Xiaoyi), a smart gateway, a smart set-top box and other smart home products. China Telecom develops customized mobile clients and open platform to provide smart living solutions for

users. Intelligent Customer Services China Telecom's intelligent customer service robot “Xiaozhi” applies AI technologies such as the neural network, the deep learning, the voice recognition, NLP, and the context scene interaction to provide the intelligent response service for users through human-computer interaction in 24*7 hours. China Telecom builds a cloud platform for intelligent customer services with the intelligent voice and semantic identification.

## Intelligent industries

### Platform:

On January 26th, 2018, China Telecom launched an AI open platform named “Deng Ta”. “Deng Ta” consists of three layers: the top layer is the application layer including the security finance, the self-driving, the smart city, the smart speaker, the smart livestock and the medical image diagnosis. The middle layer is the capability layer including the image, the video, the phonetic and NLP. The bottom layer is the foundation layer including the deep learning platform “DTaas”.

### Smart City:

China Telecom has signed strategic cooperation agreements with 236 domestic cities, cooperating in the aspects of the e-government, security, the environmental protection, the health care, the education and the tourism. China Telecom also plans to construct a smart city management platform.

### Smart Government:

In 2016, China Telecom launches a communication platform called “Ma Shang Ban” for enterprises, promoting the development of smart office and expanding enterprise market with the advantages of integration of the Internet and communication. On May 2018, China Telecom established “Tianyi Cloud Security Ecological Alliance” that provides more secure and credible cloud services for government and enterprise customers. China Telecom independently developed an intelligent system called “Zhi Cha” based on AI technologies and big data for assisting police to discover clues, analyze potential threats and deploy forces. Energy-Saving China Telecom Tianyi Cloud Company applies

the cloud computing and AI technologies to build an energy-saving system in Inner Mongolia resource pool, saving about 34 percent of the electricity consumption and 121518 yuan per year. Smart Agriculture By integrating AI and block chain, China Telecom launched an intelligent agricultural platform for agricultural product tracking. The grazing cattle and sheep's birth identity information, grassland information and quarantine information are uploaded to the platform in real time to monitor livestock growth and meat quality.

### Intelligent Transportation:

China Telecom builds an intelligent traffic management information system to combine traffic signal, cameras, weather information together, achieving real-time interaction among people, vehicles and roads. In 2018, China Telecom collaborated with BAIDU, achieving the technical test of driverless cars based on 5G in Xiongan. Telecom Fraud Prevention In January 2018, China Telecom built an AI joint laboratory with SpeakIn, committing the intelligent voice recognition in telecom fraud prevention.

## 11.4 AT&T:

American Telephone & Telegraph (AT&T) is the world's largest telecommunications company, the second largest provider of mobile telephone services, and the largest provider of fixed telephone services in the United States.

### Intelligent Networks:

AT&T released a software framework called Disaggregated Network Operating System (dNOS) hosted by the Linux Foundation to accelerate the adoption of network white boxes. The dNOS project will provide a software framework to speed up the use of white boxes in service providers' infrastructure to meet requirements of customers. AT&T designs an open hardware platform called universal Customer Premise Equipment (uCPE) on which AT&T delivers applications and services to manage enterprise networks in businesses. With this platform AT&T works with developer communities to help the entire industry in the SDN field. In July 2016, AT&T launched a security intelligence platform

called Threat Intellect. The core is an analytics and machine learning program. The analytics part watches everything happening in the network and determines if an unusual activity is worth flagging. The machine learning part means that Threat Intellect is always improving its understanding of what activity is normal. In 2018, AT&T partnered with China Mobile, Deutsche Telekom, NTT DOCOMO, and Orange to set up the Ohrand Alliance to promote the development of open-source and intelligent network. On June 27, 2018, AT&T collaborated with 12 telecom operators from all over the world such as China Mobile, SK Telecom, NTT to establish the O-RAN Alliance. The alliance introduces AI and SDN to achieve the intelligent wireless network based on big data.

## Intelligent Services:

### Smart Home:

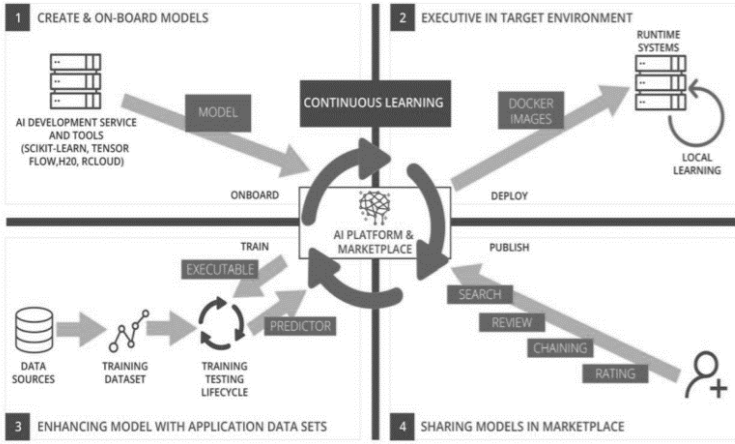
AT&T launched a smart home product called Digital Life which is designed to meet the demands of the home automation. Digital Life gives users automated control over four features. λ Locks. Users can setup custom passcodes, lock or unlock doors remotely. λ Surveillance. Users can receive notifications whenever someone approaches their home through motion detectors and sensors. λ Energy. Users can control lighting and thermostats to regulate energy usage. λ Water. Digital Life can detect water leaks and automatically shut off pipes.

### Call Center:

AT&T provides customized call center solutions from AI chatbots and emails to phone calls, IoT and the social media, helping businesses to improve customer relationships and discover new ways of revenue

### Intelligent industries platform:

In 2017, AT&T cooperated with Tech Mahindra to build an open-source AI platform, Acumos, hosted by the Linux Foundation. It makes it easy to build, share and deploy AI applications. The platform provides a marketplace for accessing, using and enhancing those applications.




On 2017, the Open Networking Automation Platform (ONAP), as a merger of AT&T's ECOMP project and China Mobile's Open-Orchestrator project, was formed. And the project began under the aegis of the Linux Foundation with China Mobile, Huawei and ZTE as leading contributors. ONAP provides a platform for real-time, policy-driven orchestration and automation of physical and virtual network functions that will enable software, network, IT and cloud providers and AI developers to rapidly deploy new services and support complete lifecycle management. In February 2018, Akraino Edge Stack, a complete software platform for edge computing systems and applications hosted by the Linux Foundation, was launched. In the project, AT&T has designed carrier-scale edge computing applications running in virtual machines and containers to support reliability and performance requirements.

### Smart City:

In 2016, AT&T launched a smart cities framework and formed the Smart City Alliance with Cisco, Deloitte, Ericsson, GE, IBM, Intel, and Qualcomm Technologies, aiming at developing solutions that could help cities address critical issues like high energy costs, transportation, aging infrastructure and public safety. Smart Medical In 2018, AT&T developed smart glasses and the "Hey Chloe" medical platform for people with poor vision to read important text such as labels on medication bottles. The platform can help people to correctly identify

prescriptions and over-the-counter medications, reducing their reliance on human agents for text recognition tasks.

### UAV:

AT&T partners with major technological companies including Intel and Qualcomm to bring drones, the machine learning and video analytics together for the cell tower inspections, as well as exploring other drone capabilities. In cell tower inspections, AT&T has a deep learning based algorithm that analyzes video footage and shows promise in detecting defects and anomalies. IoT AT&T and CarForce collaborated in the fields of AI and IoT for car dealerships. AT&T's IoT platforms combined with CarForce's AI and machine learning to help car dealerships better manage car maintenance like predicting car issues before they happen.

## 11.5 Verizon:

Verizon Wireless is an American telecommunications company which offers wireless products and services. It is the largest wireless telecommunications provider in the United States.

### Intelligent networks:

Verizon monitors network stability by using AI-driven technology and responds promptly to faults affecting customer experience in its fiber optic broadband service. The predictive analytics algorithms monitor the streaming from millions of network interfaces from customers' routers to an array of sensors. In 2018, Verizon launched a software-defined wireless local area network (SD-WLAN) service which manages both the corporate WiFi network as well as Bluetooth-enabled devices connected to the network. The service is based on Mist Systems' technologies that include AI and machine learning capabilities. The new SD-WLAN service can automatically monitor and analyze the wireless network anduser data in real time to achieve the network fault prevention and self-healing, as well as to prevent unauthorized terminal to access networks.

### Intelligent services:

On January 15, 2019, Verizon launched an end-to-end management service called Digital Customer Experience (CX) that blends human and

AI to enhance the customer engagement experience. Through Digital CX, customers will receive personalized experiences based on their past interactions.

### Intelligent industries Platform:

On February 23, 2017, Verizon launched the Exponent, a portfolio of platforms providing a broad range of business and technical benefits to carriers. It includes the big data and AI Platform, IoT Platform, the media services platform, the Internet services delivery platform and the cloud computing and storage platform. Exponent's platforms are designed to integrate the flexibility and openness of the Internet technologies with the consistency of carrier-grade solutions in order to leverage the open source software, the comprehensive APIs and micro-services architectures.

### Smart City

In 2018, Verizon collaborated with NVIDIA to attach the latter's Jetson-powered smart camera arrays to street lights in cities. The camera arrays which Verizon calls video nodes use the deep learning to analyze multiple streams of video to look for ways to increase traffic flow and enhance pedestrian safety, making cities safer and smarter

## 11.6 NTT:

Nippon Telegraph & Telephone (NTT) was founded in 1952. It's a leading telecom operator in Japan that mainly provides the phone, the video phone, i-Mode, and mail services.

### Intelligent networks:

NTT collaborated with 12 telecom operators all over the world such as AT&T, SK Telecom and China Mobile to establish the O-RAN Alliance. The alliance introduces AI and SDN to achieve an intelligent wireless network based on the big data.

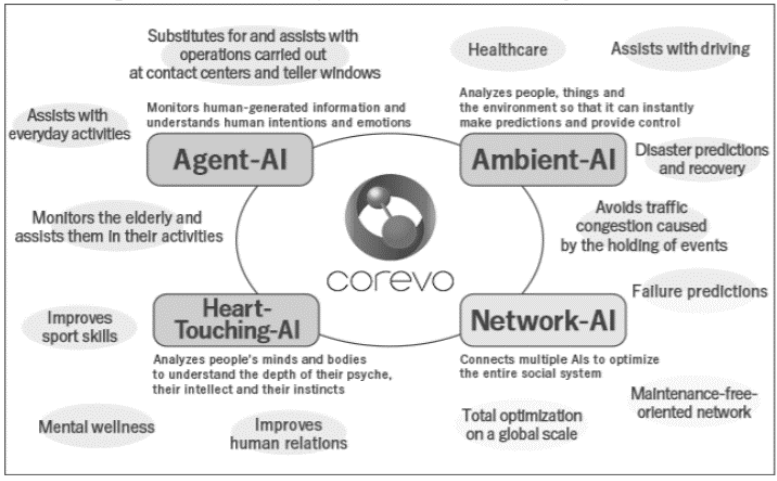
## Intelligent services:

### Smart Robot:

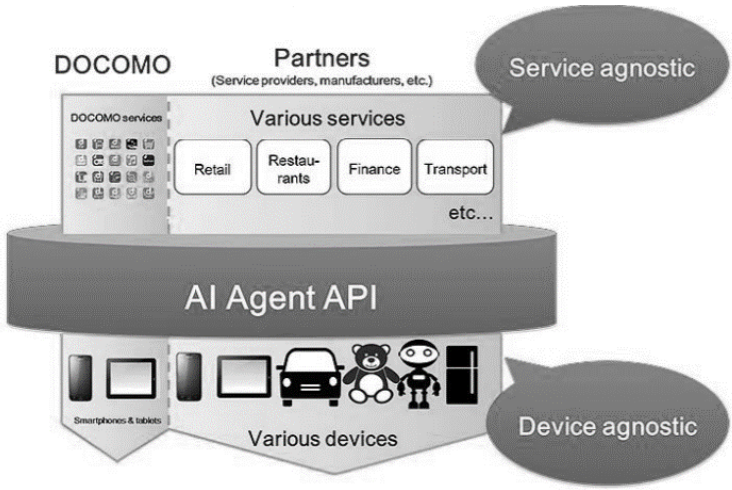
NTT DOCOMO launched OHaNAS in 2015 that is an interactive voice-activated robot and can engage in interactions by voice in Japanese. The device connects wirelessly smartphones to the natural language platform based on clouds whose proprietary is owned by NTT DOCOMO. NTT West launched the service robot called “Sota” in December 2016 that interacts with people in English and Chinese. “Sota” is connected to NTT AI platform “Corevo” to get customers’ information such as their nationality and intention. “Sota” also can provide care services for old people.

### Intelligent industries Platform:

NTT Group launched the “Corevo” AI platform in 2016, which mainly focuses on four directions: “Agent-AI”, “Heart-Touching-AI”, “Ambient-AI” and “Network-AI”. “Agent-AI” is used to understand the intentions and emotions in the information sent by human and interact with people. “Heart-Touching-AI” is used to analyze and understand people's deep psyche, intellect and instincts. “Ambient-AI” is used to analyze and understand the world, and predict some situations. “Network-AI” is used to evaluate and optimize the social system with AI technologies.



NTT DOCOMO launched its new AI Agent Open Partner Initiative on June 2017 to facilitate collaborative development for speech interfaces of the service-agnostic and the device-agnostic functions. NTT DOCOMO expects to create an open environment for diverse services that use AI technology.




### Smart City:

NTT Group expanded its partnership with Dell Technologies to launch the smart city initiatives in 2018. The proof of concept with the Las Vegas is first performed as part of its digital transformation.

### Intelligent Security:

In 2018, NTT East partnered with the startup Earth Eyes Corp to release a security camera called “AI Guardsman”. It is based on machine learning techniques and gives CCTV cameras the ability to spot troubling behaviors without human supervision. The camera uses open source technology to scan live video streams and estimate the poses of any bodies it can capture and then tries to match this pose data to look for suspicious behaviors.

### Intelligent Transportation:

NTT collaborated with Toyota Motor on high-speed wireless technology to commercialize safer self-driving vehicles in 2017. The two companies

jointly developed technologies for cars utilizing 5G networks. Smart Retail In March 2018, NTT DOCOMO launched an AI engine that accurately analyzes shelf allocations in stores and warehouses with photos taken by smartphones and other common devices. Image recognition and object detection technologies are applied in the engine. It is expected to be used widely in the distribution and retail industries for product-shelf management and sales analysis.

## 11.7 SoftBank:

SoftBank is a Japanese telecom operator and venture capital firm whose businesses mainly include the broadband, the fixed line telephony, the e-commerce and the Internet. Since SoftBank launched the Yahoo! BB service to provide the broadband ADSL services in 2001, it had officially entered the telecom field and become a leading telecom company in Japanese.

### Intelligent networks:

SoftBank partnered with Ericsson to improve the RAN design by using a network automation service in 2018. The technology applies the machine learning and big data analytics to enable automation. Two companies conducted the analysis on the radio network, which includes the cell coverage overlap, the signal strength and the receiving diversity. SoftBank launched a vacuum robot Called “Whiz” in November 2018 that is powered by AI and is regarded by the company as a potential remedy to Japan's labor shortage

### Intelligent services:

Smart robot In 2014, SoftBank launched a semi-humanoid robot called “Pepper”. It is designed to interact with customers by analyzing expressions and voice tones with the ability to detect emotions. On August 2018, SoftBank announced that “Pepper” started to use the emotion recognition from a technology company named Affectiva to interpret and respond to human activities.

### Intelligent industries:

In 2017, SoftBank partnered with Honda launched an electric car called "NeuV". The car is able to gauge the driver's emotions and engage in conversations by cameras and sensors in it.

### IOT:

In December 2017, SoftBank and startup Inuitive Ltd. announced the collaboration on AI and IoT. The collaboration focuses on the pioneering applications of 3D sensor, validating the performance of sensor chips developed newly by Inuitive, and testing solutions that combine Inuitive's AI chips and SoftBank's IoT platforms.

## 11.8 SK Telecom:

SK Telecom, founded in 1984, is the South Korean's largest wireless telecommunication operator. It is part of the SK Group, one of the country's largest chaebols. SK Telecom is the world's first operator to implement 3G mobile networks. SK Telecom is also the world's first operator to commercialize 5G mobile networks.

### Intelligent networks:

In 2017, SK Telecom announced that the company expanded the application of the "T Advanced Next Generation Operational Supporting System", known as TANGO, to all telecommunications networks of the company. TANGO is an AI-assisted network operation system with big data analytics and machine learning capabilities. The system delivers the automated detection of issues on the network, the troubleshooting of problems, and the performance optimization.

### Intelligent services:

Smart Voice Assistant In 2016, SK Telecom launched its AI based voice assist service called "NUGU", which is the first virtual home assistant service that understands and processes the Korean language. Consumers can interact with the device to give it commands such as controlling mobile applications and query information on the Internet. SK Telecom launched several products based on NUGU like the NUGU mini and BTV×NUGU. BTV×NUGU integrates IPTV set-top boxes and the AI

platform NUGU together to control other intelligent devices in home. SK Telecom with Xilinx Inc. announced that SK Telecom had deployed Xilinx's FPGAs as their AI accelerators in its data center on August 2018. The FPGAs accelerate the automatic speech-recognition application of NUGU. Smart Home SK Telecom launched GiGA Genie in 2017 that is a smart set-top box and can manage IPTV, the Internet phone, IoT and other smart devices.

### Intelligent industries

Intelligent Transportation SK Telecom launched an in-car virtual assistant called "T Map×NUGU" in 2017. The AI-based vehicle navigation system enables drivers to access existing navigation functions and real-time traffic information by voice, and to use the voice command to adjust the volume, end the service, close the applications, etc

## 11.9 Vodafone:

Vodafone Group plc headquartered in London, is a British transnational mobile phone operator. Vodafone is one of the largest mobile communication network corporations, and makes investment around 27 countries. Vodafone collaborates with other 14 countries' local mobile phone operators on mobile phone network service. The name of Vodafone means Voice, Data, and Phone, which is also its global strategy.

### Intelligent networks:

Vodafone Germany and Huawei trialed the Centralized Self-Organizing Network (C-SON) to identify the optimal settings to deliver voice over LTE services across 450 mobile cells chosen at random. Vodafone Ireland and Cisco use the machine-learning algorithms in C-SON to predict locations where 3G traffic will peak in the following hour. The program predicts the network traffic behavior based on data processing and pattern recognition. The predictions enable the network to configure itself automatically, balance the traffic load among neighboring cells, and improve the customer experience. Vodafone uses the AI technology from Ericsson and Huawei to reduce incidents, improve fault management, and improve user experience by ensuring the system to

automatically choose the best frequency or node for each mobile connection.

## Intelligent Services:

### Smart Home:

V-Home, an intelligent home IoT service, is Vodafone's latest smart home value-added business solution under the premise of the development of the IoT. V-Home aims to let customers know what is happening at home anytime and anywhere.

## Intelligent Customer Service System:

Vodafone UK has launched an AI chatbot named TOBi. Users can download My Vodafone app or login to Vodafone's website to use TOBi. TOBi is powered by IBM Watson and LivePerson. TOBi can help deal with customer services such as the phone maintenance, the account usage queries, and the order tracking. Vodafone revealed that TOBi can achieve seamless handover. It helps Vodafone to reduce the cost and improve customer service by shortening the responding time of questions.

Vodafone launched a virtual agent "Hani" that uses the intelligent chatbot technology to support and enhance the consumer digital service. Hani answers 80,000 enquiries per month. The staffs in call center use Hani to get accurate and up-to-date information of Vodafone products and services. Vodafone Italy officially launched "Vodafone Bot", an AI system that provides real-time answers to simple questions of clients.

## Intelligent Interview:

Vodafone uses AI to interview more than 50,000 applicants for its call center and customer service jobs. After potential applicants recorded their responses in videos to standardized questions, robots analyzed videos based on 15,000 factors. These factors include the body language, facial expressions, and the tone of voice. If applicants pass the AI test, they will be invited to an interview of a real person. Vodafone said that the recruitment time is cut in half and hired people have better "attitude".

### Intelligent Industries:

#### Intelligent UAV:

Vodafone developed the world's first Radio Positioning System (RPS) for UAVs. Vodafone's RPS, combined with the AI algorithm developed by itself, can track and monitor a large number of UAVs remotely. A series of experiments were conducted in 2017 and 2018 with the aim of the commercial use in 2019. Smart City Vodafone proposes the Ready City project to lay out the global smart city business. On the one hand, Vodafone actively develops its own vertical industry solutions, including the waste management, the smart energy, the smart transportation, and so on. Taking the waste management as an example, Vodafone embedded its M2M SIM card into the garbage bin to help garbage classification and detect whether the garbage bin is full. On the other hand, Vodafone also provides services through the strategic cooperation with partners, including the smart street lights, the smart water management, the smart parking, and so on.

## 11.10 Telefonica:

Telefonica is a Spanish telecom operator. Telefonica provides services of the fix communication line, the mobile phone, the Internet, the cable TV, and so on. Telefonica has a strong influence in countries that speak Spanish and Portugal.

### Intelligent networks:

Telefonica collaborated with Juniper Networks to develop the Self-Driving Network. The collaboration aims to transform the network infrastructure provided by Telefonica into an automated network that is capable of the automatic discovery, the automatic analysis, the automatic tuning and the automatic correction. Hence, the business development will be accelerated with lowering the operating cost and enhancing security and flexibility.

### Intelligent Services:

#### Intelligent Virtual Assistant :

Telefonica announced the launch of Aura that is an AI-powered digital assistant and will transform the way customers interact with Telefonica

on February 25th 2018 in MWC Barcelona. Aura will be firstly used in Argentina, Brazil, Chile, Germany, Spain and the United Kingdom.

### Smart Home:

Telefonica announced the launch of the smart home equipment on February 25th 2018 in MWC Barcelona, Movistar Home, which will integrate Aura's intelligence into all its services. Movistar Home aims to become a hub where users can connect and manage all the devices in houses.

### Smart Notifications:

Telefonica launched Smart Notifications on February 9, 2018, an AI or machine learning solution for mobile applications to optimize the delivery of notifications to users. The solution aims to intelligently select the best moment during a day to send notifications when users are most receptive to interactions.

## Fourth Platform

Telefonica announced the launch of the 'Fourth Platform' at MWC 2017.

Telefonica's fourth platform is a determined move towards positioning itself as a 'smart telco' instead of a 'dumb pipe'.

## Intelligent Industries

### Smart Energy:

Telefonica launched the smart energy business. The smart energy offers solutions that enable Telefonica's customers to monitor their energy consumption and apply specific savings measures.

### Smart Retail:

Telefonica launched the smart retail business. It encompasses a set of technological solutions enabling the convention from a conventional physical store into an interactive point of sale, which meets the digital revolution. It also provides retailers with the necessary tools to obtain detailed information of their business and customers, increasing their sales and operating processes.

### Smart Transportation:

Telefonica launched the smart transportation business, Smart Mobility. Smart Mobility includes solutions for the fleet management, the asset tracking, the car connection, etc., making the transportation of goods and people more efficient and safe.

### Smart City:

Telefonica launched the smart city business. The smart cities platforms can gather information from different sources such as sensors, city council's systems or citizen's smartphones. It contributes to the development of a sustainable city by improvements in environmental and economic efficiency.

## 11.11 Orange:

Orange is headquartered in Paris. It is the first mobile operator in Britain and France, and one of the largest telecom operators in Europe. The main services are the mobile, the landline, the Internet and IPTV.

### Intelligent networks:

Orange revealed an AI research project in detail with IBM and Nokia that could predict demand patterns in future for 5G networks and avoid the "overprovisioning" of network resources.

Orange is actively promoting the digital transformation of network. It involves the improvement of the quality of the network services by introducing AI technology in the network optimization and SDN/NFV, and the process of the video content with AI technology.

Orange launched a security and anti-fraud solution that consists of four steps: statistics, detection, protection, and notification. The statistical step provides an in-depth analysis report on potential or known vulnerabilities. The detection step is to monitor threats in real time. The protection step intervenes and intercepts cheating in real time. The notification step is to send a security report to users.

## Intelligent Services:

### Smart Home:

Orange France launched Homelive, a smart home solution that combines its own smart home product, Livebox, to form a small but rich ecological closed loop. In spring 2019, Orange will launch the “Connected Home” service in France. This service will make it possible to directly connect objects to Livebox and manage them remotely through a single application accessible via a smartphone or a TV.

## Intelligent Virtual Assistant:

Djingo is the intelligent assistant from Orange that can be controlled by voice or text. It offers an easy and intuitive way for users to watch the Orange TV, manage connected devices, make a call, etc. Smart Speaker Orange developed a smart speaker with Deutsche Telekom based on Djingo. The smart speaker is voice-controlled and is the interface for all Orange services. So, it becomes a telephone to make hands-free calls at home and it can be used to interact with Orange TV and to control all the “Connected Home” services.

## Intelligent Industries:

### Smart Agriculture:

Researchers of Orange Labs are working on a business AI solution in collaboration with pig farmers in Brittany to digitize the farming data, aiming to help farmers produce better quality meat at a lower cost. Orange Business Services, which is a subsidiary of Orange and specializes in IT solutions services, applies Huawei's AI technology to wineries. The vineyards are managed intelligently by monitoring pests and diseases with data from satellites, cameras and sensors on agricultural machinery.

## VR/AR

Orange with partners launched the AR/VR product called Holotenins. It provides an immersive experience for people equipped with VR headsets. Orange launched a virtual tour service called Look Around. It offer users a touring experience of virtual immersion with technologies

of AI, the 360-degree immersion, the big data, and so on. It is also a smart assistant able to answer visitor's questions about the destination.

## 11.12 Deutsche Telecom:

Deutsche Telekom, headquartered in Bonn Germany, is the largest telecom operator in Europe and the fifth largest in the world. “T” is the brand sign of Deutsche Telekom and other global subsidiaries such as the famous T-Mobile and T-system.

### Intelligent networks:

Deutsche Telekom is breaking new ground in its fiber optic roll-out, becoming the first network operator in Europe to plan a pilot project using AI. The pilot will be carried out with the help of a special vehicle that gathers precise data about the environments via various sensors and laser-scanning technology. The data will be translated into georeferenced 3D image data. The system learns to recognize landscape features, such as houses, grass, trees. The system is also able to incorporate available reference data such as street maps. As a result, it can rapidly produce precise proposals for ideal routes for subterranean cables.

The project is being carried out in cooperation with Fraunhofer. Deutsche Telekom unveiled an application names CONNECT to find the best available Internet connection. There are various ways to connect to the Internet, 3G, 4G, hotspots or Wi-Fi with different price, thus, it is not easy for users to choose the best way of the Internet connection. Although some users do not care the way to connect the Internet, the majority of users are affected by price, the network speed and security. Manually changing connections is inconvenient.

The CONNECT app uses the machine learning technology to help users choose the “Best connection” or the “WiFi preferred”, as well as gives customers a full control of the high speed and cost. It provides a fast access to the Internet with high security. An integrated VPN encryption enhances the data privacy when the public Wi-Fi networks are chosen.

## Intelligent Services

### Smart Home:

Deutsche Telekom has launched a smart home business platform, Qivicon. It mainly provides back-end solutions, including smart home terminals for users and the integrated software development and maintenance platform for enterprises.

### Intelligent Virtual Assistant:

Deutsche Telekom launched a chatbot acting like a virtual employee, Tinka, aiming to assist customers in Austria at any time of a day. Tinka is an icon of a young woman with long hairs. She has learned over 1,500 answers. If she can't answer the questions, she will forward it to a customer service agent. Connecting customers to customer service agents is one of her strengths. If the agent is not available right now, she will recommend customers send emails to the agent. Besides, the company owns other virtual assistants including the Sophie and Vanda.

### Smart Speaker:

Deutsche Telekom plans to begin offering its customers the Smart Speaker, an intelligent personal digital assistant. The Smart Speaker is able to manage all connected devices in users' home by voice commands, including Deutsche Telekom's EntertainTV and the Magenta Smart Home applications. Therefore, operations like changing channels, dimming lights and adjusting room temperature can be done through voice.

### Intelligent Recruitment System:

Deutsche Telekom uses the hub:bot, an AI-supported chatbot designed by its startup incubator Hub:raum, to improve job seekers' experience and efficiency in the interview. The hub:bot can answer applicants' questions immediately and is available 24*7. It saves applicants' time on making appointments and waiting for the responds. The hub:bot also enhances the efficiency of recruiters by help them weed out applicants who are completely unfit for the job

### Intelligent industries:

#### Smart City

Deutsche Telekom unveiled a new smart city app and announced a new smart city platform. The platform will facilitate residents to access data about the city, including sightseeing opportunities, the location of Wi-Fi hotspots and taxi stands, as well as the waste collection time.

## 11.13 Singtel

Singapore telecommunications limited, abbreviated as Singtel, is the Singapore's largest telecom operator which has 640 million users. Singtel provides the network service (SingNet), the IPTV service (Singtel TV), the mobile phone networks (Singtel Mobile) and the fixed line telephony services.

### Intelligent networks

On June 27, 2018, Singtel collaborated with 12 telecom operators from all over the world such as China Mobile, SKT&T, NTT to establish the O-RAN alliance. The alliance introduces AI and SDN to fulfill the intelligent wireless network based on big data.

### Intelligent services

#### Smart home

In August 2018, Singtel showcased technologies for the smart home which include the home system controlled voice and IoT for consumers. All functions are managed seamlessly through Singtel's smart platform FIC.

### Intelligent industries

#### Platform

In August 2018, Singtel launched its FutureNow Innovation Center (FIC) platform to support the government and enterprise's digital transformation. FIC applies AI, SDN, data analytics and other emerging technologies, and serves as a platform for technology partners to perform collaboration and innovation.

### Smart Retail

In August 2018, Singtel established an innovation center with Chinese smart retailer Comma Smart, expanding the smart retail market in Singapore with the help of AI technologies. Others In December 2017, Singtel collaborated with Nanyang Technological University and Singapore's National Research Foundation to set up Singtel Cognitive and Artificial Intelligence Lab for Enterprises (SCALE), which focuses on the research of AI technologies, big data and IoT.

The lab also develops industrial applications such as the pubic security, the transportation, and the health care in next five years. In December 2017, Singtel signed a five-year Master Research Collaboration Agreement with Singapore Agency for Science, Technology and Research. The agreement announces that both will jointly research smart buildings, robots and IoT applications. Singtel also will test these new technologies in scenarios of 5G and NB-IoT in its Advanced Remanufacturing and Technology Centre.

On June 29, 2018, Singtel signed the memoranda of understanding (MOU) with National Supercomputing Center (NSCC) Singapore, Nanyang Technological University and Chinese corporation SenseTime. The collaboration aims to promote AI technologies and research solutions for the demand of the industrial development in Asia. Singtel is the largest telecom operator that participates in Singapore National Research Foundation (NRF)'s AI project called "AI.SG", aiming to promote the development of domestic AI technologies.

The project gathers AI research institutions, technology firms and industry companies together to build AI knowledge base, develop advanced products and cultivate AI talents. In August 2018, AI.SG introduced two AI plans, "AI for Everyone" (AI4E) and "AI for Industry" (AI4I), to energize industries with AI technologies

## 11.14 Bharti Airtel

Bharti Airtel limited, an Indian company of telecom services, is the largest local mobile network operator in India and the third largest in the world in the aspect of subscriber count. The company's products include 2G, 3G and 4G wireless services, the mobile commerce, the fixed line services, the high speed home broadband, DTH and enterprise services.

### Intelligent networks:

In September 2017, Bharti Airtel announced that they start to expand TANGO, an AI-assisted network operation system with big data analytics and machine learning capabilities developed by SK Telecom on mobile networks to improve the customer experience.

### Intelligent services:

On November 8, 2017, Bharti Airtel announced a strategic partnership with software solutions provider Amdocs to bring AI-based services to its customers in India. Both partners will apply the machine learning and advanced AI-based technologies across Bharti Airtel's businesses. It helps Bharti Airtel to deal with the self-healing operations and introduce smart chatbots. On October 3, 2018, Bharti Airtel acquired the intellectual proprietary rights for the Callup AI and the Fintech OCR, two flagship solutions developed by a Bengaluru-based start-up AuthMe ID. The Callup AI is a voice/chat assistant that uses AI to resolve customer queries over emails, chats and phone calls. The Fintech OCR is designed for processing financial documents.

### Intelligent industries:

On July 10, 2017, Bharti Airtel launched "Project Next". This project is a digital innovation program, aiming at transforming customer experience across all of its services and touchpoints. Bharti Airtel also set up a digital innovation lab in Bengaluru to work on emerging technologies such as AI, IoT, AR/VR as part of its broader strategy to develop technology capabilities.

# Chapter - 12

# Discussions About AI Applications In Telecom Operators

## 12.1 Intelligent networks:

The typical researches and results of telecom operators in the intelligent network are as follows.

| Classification | Telecom Operators | Typical Researches and Results |
|---|---|---|
| Current network | China Mobile | ACOS, APOS, AIOps. |
| | China Unicom | AR intelligent operation and maintenance system |
| | | Awareness & Analysis system for network situational |
| | | AI applied in Roots-tracing of Network Alarm |
| | AT&T | disaggregated Network Operating System (dNOS) |
| | | universal Customer Premise Equipment (uCPE) |
| | | Threat Intellect platform for network security |
| | Verizon | SD-WLAN service based on AI system Mist |
| | SK Telecom, Bharti Airtel | T Advanced Next Generation Operational Supporting System (TANGO) |
| | Vodafone | Analysis and prediction for Centralised Self-Organising Network (C-SON) |
| | Orange, Deutsche telekom | AI in network optimization, fault detection, etc. |

The use cases above show that the intelligence is more and more urgent for the development of network. Following this tendency, operators conduct researches and cooperation to make networks intelligent.

Regarding applications of AI in the current network, operators' concentrations mainly are the intelligent operation and maintenance, and the intelligent optimization.

AI technologies have helped operators to monitor the network status in real time and enabled the network to adapt to different business scenarios through self-regulation. The exploration for application of applying AI in the future networks such as SDN/NFV and 5G is under way. At present, SDN/NFV is being deployed, and 5G will be in commercial use.

The introduction of AI will probably solve many problems for the future networks like reconfiguration. Telecom operators also cooperate to take their own advantages, and form numbers of alliances or groups to research the intelligent network. For example, the O-RAN Alliance established by China Mobile, AT&T and 10 other operators, introduces AI and SDN to make the wireless network intelligent. The Ohrand Alliance established by NTT, Orange and 3 other operators, promotes the development of the open-source and intelligent network.

## 12.2 Intelligent Services

The typical researches and results of telecom operators in intelligent services are as follows.

| | | |
|---|---|---|
| Customer Services | China Mobile | The interactive robot "Yiwa" |
| | China Unicom | The business-driven adaptive network<br>The energy-saving system based AI for data centers |
| | China Telecom | The intelligent customer service robot "Xiaozhi" |
| | Verizon | The end-to-end service Digital Customer Experience (CX) |
| | NTT | The service robot "Sota", the interactive robot "OHaNAS" |
| | Softbank | The interactive robot "Pepper" |
| | SK Telecom | The voice assist service speaker "NUGU" |
| | Vodafone | The intelligent customer service robot "TOBi", "Hani", and "Vodafone Bot" |
| | Telefonica | The intelligent assistant "Aura" |
| | Orange | The intelligent assistant "Djingo" |
| | Deutsche Telekom | The intelligent assistant "Tinka", "Sophie" and "Vanda" |

The use cases above shows that operators are actively promoting intelligent services. The researches and products mainly focus on the smart home and the intelligent customer service. For smart home, operators develop and promote smart terminals based on AI technologies since they have advantages of accessing home customers.

The products such as the smart speaker and the smart set-top box are considered as the entrance of the smart home for telecom operators. For the intelligent customer service, telecom operators use AI technologies such as the speech recognition and the natural language processing to develop the voice assistant, achieving the interaction between customers and chatbots. The voice assistant saves a great deal of labor costs.

## 12.3 Intelligent industries:

The typical researches and results of telecom operators in the intelligent industries are as follows.

| Intelligent Industries | Telecom Operators | Typical Researches and Products |
|---|---|---|
| Platform | China Mobile | The AI platform “Jiu Tian” |
| | China Mobile , AT&T | ONAP |
| | China Telecom | The AI platform “Deng Ta” |
| | AT&T | The open source AI platform “Acumos” |
| | | The edge computing platform “Akraino Edge Stack” |
| | Verizon | A portfolio of platforms “Exponent” |
| | NTT | The AI platform “Corevo” |
| | | The AI Agent Open Partner Initiative |
| | Singtel | The AI platform “FutureNow Innovation Center (FIC)” |

The use cases above show that telecom operators are using the AI technology to expand businesses in vertical industries. On the one hand, telecom operators develop AI platforms to integrate the network capability and the AI applications in order to comprehensively enhance the management ability and the service ability.

On the other hand, telecom operators set to develop core technologies of AI and extend their business fields to vertical industries. The results show that telecom operators are providing the integrated digital services to customers in the fields of agriculture, transportation, retail, security and medical treatment.

# Chapter - 13

# Suggestions For Applying AI To Telecom Operators

At present, applications of AI technology in telecom operators are only in its infancy, but it has bright prospects in many fields. It is a great opportunity for telecom operators to deploy AI in platforms, networks, services and industries.

Build an Open Platform with AI Capabilities Telecom operators should integrate their data with computing capabilities and introduce AI technologies to build an open platform with AI capabilities and form an integrated service capability.

Develop an Intelligent Network Telecom operators should make full use of the powerful capabilities in analysis, judgment and prediction provided by AI algorithms to enable network elements, networks and business systems. For 3G, 4G and other existing communication networks, the AI technology is applied to the aspects of the planning, the design, the construction, the maintenance, and the optimization for networks in order to improve efficiency and reduce cost. In future networks such as 5G, SDN/NFV and the edge cloud, the AI technology is applied to the network management to meet the challenge of the increased network complexity.

Improve Service Quality Telecom operators should take their advantages of data and AI technology to develop the intelligent customer service system, the smart business hall, the smart home and other service applications, enhancing customer service quality, reducing labor costs and improving the user experience.

Expand Diversified Industries Telecom operators should pay attention to scenario-driven applications, explore AI applications in the medical

industry, the financial industry, the retail industry, the education industry, the home industry, the manufacturing industry and other industries, launch AI solutions in various fields, and enhance business competitiveness.

In summary, the development of applications of AI technology to telecom operators will progress in both internal and external directions. The internal application of the AI technology aims to improve the network quality and achieve reduction in cost and increment in efficiency. Regarding the external aspect, building the AI industry chain by cooperation between businesses becomes the focus for telecom operators.

# Chapter - 14

# AI Trends Changing In Telecom Industry

Artificial Intelligent applications are transforming the way telecoms function, optimize, and render service to their customers.

Today's communications service providers (CSPs) suffer increasing customer requirements for higher quality services and excellent customer experiences (CX). Telecoms are approaching these opportunities by leveraging the massive amounts of data collected over the ages from their massive customer foundation. This data is harvested from mobile applications, geolocations, devices, networks, detailed consumer profiles, services regulation, and billing data.

Telecoms are controlling the power of AI to prepare and analyze these enormous volumes of Big Data in order to obtain actionable insights to provide better customer expertise, improve operations, and raise revenue through new commodities and services.

With Gartner predicting that 20.4 billion connected devices will be in practice worldwide by 2020, more and more CSPs are hopping on the bandwagon, understanding the value of artificial intelligence applications in the telecommunications arena.

## Network Escalation

AI is required for helping CSPs build self-optimizing networks (SONs), where engineers have the ability to mechanically optimize network quality based on transactions information by region and time meridian. Artificial intelligence applications in the telecommunications sector use advanced algorithms to watch for patterns within the data, allowing telecoms to both detect and prognosticate network anomalies, and enabling operators to fix problems before customers are negatively influenced proactively.

IDC intimates that 63.5 percent of telecoms are spending in AI systems to improve their infrastructure. Some convenient AI solutions for telecoms are ZeroStack's ZBrain Cloud Management, which investigates private cloud telemetry storage and utilize it for improved capacity preparation, upgrades, and comprehensive management. Aria Networks, an AI-based network optimization explication that counts a growing quantity of Tier-1 telecom businesses as customers, and Sedona Systems' NetFusion, which merges the routing of traffic and speed transmission of 5G-enabled services like AR/VR. Nokia propelled its own machine learning-based AVA platform, a cloud-based network administration solution to manage capacity preparation better, and to predict co-operation degradations on cell sites up to seven days in advancement.

## Predictive Preservation

AI-driven predictive analytics are supporting telecoms provide better assistance by utilizing data, advanced algorithms, and machine learning procedures to predict future decisions based on historical data. This means telecoms can utilize data-driven insights to observe the state of equipment, foretell failure based on patterns, and proactively repair problems with communications hardware, such as power ranges, cell towers, data center servers, and even set-top receptacles in customers' homes.

In the short-term, network computerization and intelligence will enable better source cause analysis and prediction of problems. Long term, these technologies will promote more strategic goals, such as designing new customer experiences and distributing efficiently with business demands.

## Virtual Associates

Conversational AI platforms—identified as virtual assistants—have acquired to automate and surmount one-on-one conversations so entirely that they are projected to cut business rates by as much as USD 8 billion in the next five years. Telecoms have shifted to virtual assistants to assist with the significant number of support applications for installation, troubleshooting, and sustenance, set up, which often confuse customer support centers. Using AI, telecoms can perform self-service capabilities

that instruct consumers on how to install and administer their own devices.

## Robotic Process Automation (RPA)

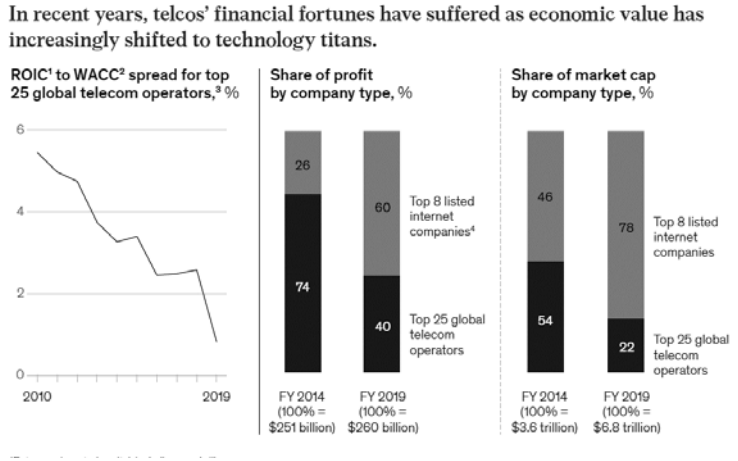
CSPs all have huge amounts of customers and an unlimited volume of daily transactions, each receptive to human error. Robotic Process Automation (RPA) is a sort of business process automation technology based on AI. RPA can bring excellent efficiency to telecommunications purposes by allowing telecoms to more effectively manage their back-office operations and the massive amounts of repetitive and rules-based methods. By streamlining the execution of once tricky, labor-intensive, and time-taking procedures such as billing, data entry, employee management, and order satisfaction, RPA disengages CSP staff for a higher value-add operation.

As per a study by Deloitte, 40 percent of Telecom, Media and Technology officials say they have accumulated substantial benefits from cognitive technologies, with 25 percent having invested USD10 million or more. More than three-quarters anticipate cognitive computing to considerably transform their organizations within the next few years.

Artificial intelligence (AI) is the science of creating intelligent machines capable of autonomously making decisions based on their perceived environment. Machine learning (ML), a branch of AI, enables this learning paradigm . Typically, ML is typically thought of as a universal toolbox, ready to be used for classification problems, identifying a suitable category for a new set of observations, and regression tasks, estimating the relationship among given data samples.

In fact, it is a diverse field comprised of various constituents and necessitates: a software ecosystem including data monitoring and transformation, model selection and optimization, performance evaluation, visualization, and model integration, to name a few. Explicitly, ML refers to computational representation of a phenomenon aimed at execution of a task, given a certain performance and based on a given environment ML approaches may be categorized based on objectives of the learning task, where these objectives may target pattern

identification for classification and prediction, learning for action, or inductive learning methods.




The algorithms may be further classified into three distinct learning families, i.e., supervised learning, unsupervised learning, and reinforcement learning. Semi-supervised learning, or hybrid learning, is sometimes considered a fourth branch, borrowing features from the supervised and unsupervised categories.

(i) Supervised Learning: Supervised learning (SL) makes use of known output feature(s), named labels, to derive a computational relationship between input and output data. An algorithm iteratively constructs a ML model by updating its weights, based on the mapping of a set of inputs to their corresponding output features. SL may be further categorized into classification and regression tasks, depending on whether discrete or continuous output features are used.

(ii) Unsupervised Learning: While SL provides a clean-slate approach to ML model construction, in practice, labeled data is neither easily accessible nor abundantly available. Unsupervised learning (USL) aims to build representation of a given data set without any label-driven feedback mechanisms. USL may be further classified into clustering of data into similar groups, or association rule discovery, identifying relationships among features.

(iii) Reinforcement Learning: Reinforcement learning (RL) refers to ML mechanisms without an explicit training phase . RL aims to build and update a ML model based on an agent's interaction with its own environment. The key difference with respect to SL techniques is that labeled input–output features are not provided, but the relationship is rather learned via application of the initial model to test data. Machine learning is currently perceived as a paradigm shift for the design of future networks and systems.

(iv) These techniques should allow to infer, from data obtained by various types of monitors (e.g., signal quality, traffic samples, etc.), useful characteristics that could not be easily or directly measured. Some envisioned applications in networking can include fault prediction, intrusion detection, security, routing, low-margin design, traffic-aware capacity reconfigurations, but many other can be envisioned.

(v) Transforming a legacy stack cobbled together over decades of business evolution and M&A is extremely costly and slow, so many operators are choosing to decouple and deploy a greenfield IT stack that is fully cloud native and leverages open-source technologies. With evolutions in open source and cloud, a reimagined stack is affordable, easy to maintain, and can accommodate quick changes. This approach has enabled an APAC operator to reduce capital expenditure by 80 percent and a European operator to increase IT velocity—the time it takes to go from feature definition to release—by up to ten times.

# Chapter - 15

# Favorable Trends In Telecom Industry With AI

## Network Operations Monitoring and Management:

One of the many challenges obstructing the operational decision making for telecoms is the virtualisation of networks, to scale them for the 5G upgrade. This is certainly not a quick win but has many stumbling blocks. Not only network providers have to centralise their network management, but they need to ensure the delivery of profitable services to end-customers as well. Tuple applies machine learning algorithms to identify & predict issues in the network and notifies before these issues escalate into emergencies. The data-driven applications provide a centralised platform for unification of all the operational data including device logs, where the automated predictive analysis alerts with valuable insights on the root cause to reduce the resolution time.

## Reducing Customer Churn:

Customers today demand more than a generic call & data service from their telecom service provider. Pricing promotions, weaker connection capabilities, slow customer service & billing disputes are just a few of many reasons customers tend to leave a network provider. Tuple uses advanced analytics to provide a comprehensive view on the entire customer journey including product, offer, usage, & rebate history by unifying structured, unstructured data from call centres, pricing & promotions, weblogs & network experience. The advanced algorithms give highly accurate predictions on customer behaviour & identify contributing variables.

## Automate Customer Support System:

Telecom companies tend to have a large user base, with every customer demanding instant resolution. Managing communication through calls & written text for this dense volume is exigent. The customer support teams juggle myriad of queries ranging from network issues, billing to device setup. Tuple's chatbot is modelled with advanced machine learning algorithms & is programmed to efficiently manage a variety of chats at the same time. By leveraging Natural Language Processing (NLP), the conversational interface of Nova is trained to understand the intent of every message customer used to interact & to account for entire conversation before responding with a resolution of the relative query.

## Fraud Detection and Prevention:

Telecom frauds cost billions to the industry revenue & the complaints continue to add up every year. To avoid fraudulent attempts, companies need to keep a sharp monitoring eye on suspicious calls, as they tend to take advantage of customer's lax security practice. Tuple puts data analytics in action to analyse the enormous call traffic in real-time, to identify suspecting call patterns. We automate real-time call routing decisions by analysing different data-points like customer status, purchase history with predictive AI and this way, network operators can prevent the fraud before the eruption.

## Improved Customer acquistion:

To acquire new customers who would lead to increased sales, telecom companies need to improvise their product recommendations by analysing what exactly their customers are looking for - be it a better price, added volume of internet, or other OTT benefits. Tuple helps network operators in making the right recommendations, to the right customer and at the right time. Our AI-powered recommendation engine gives accurate insight for cross-selling new services, matching pricing plans, or making personalised offers for customers.

# Chapter - 16

# Challenges In AI Wireless System

Radio resources are scarce, and there is an increasing demand of wireless traffic. Intelligent wireless network management is the way forward to meet these increasing demands. Machine learning/deep learning can be a promising feature for resource allocation in 5G wireless communication networks.

Deep learning can be a good alternative for interference management, spectrum management, multi-path usage, link adaptation, multi-channel access, and traffic congestion. For instance, the author proposed an AI scheduler to infer the free slots in a multiple frequencies time division multiple access to avoid congestion and high packet loss.

Four last frames state are fed to a neural network, which consists of two fully connected hidden layers. The proposed AI scheduler was tested in a wireless sensor network of 5 nodes and can reduce the collisions with other networks with 50%.

The author proposed the addition of the artificial intelligence module instead of replacing conventional scheduling module in LTE systems.

This AI module can provide conventional scheduling algorithms with the flexibility and speed up the convergence time. As scheduling for cooperative localization is a critical process to elevate the coverage and the localization precision, the authors presented a deep reinforcement learning for decentralized cooperative localization scheduling in vehicular networks.

The authors proposed a deep reinforcement learning (DRL) based on LSTM to enables small base stations to perform dynamic spectrum access to an unlicensed spectrum. The model enables the dynamic selection of wireless channel, carrier aggregation, and fractional

spectrum access. The coexistence of WLAN and other LTE-LAA operators transmitting on the same channel is formulated as a game between the two and each of which aims to maximize its rate while achieving long-term equal-weighted fairness. This game is solved using DRL-LSTM. The proposed framework showed significant improvement.

The authors proposed an AI framework for smart wireless network management based on CNN and RNN to extract both the sequential and spatial features from the raw signals. These features serve as a state of deep reinforcement learning which defines the optimal network policy. The proposed framework was tested using real-experiment an experiment using a real-time heterogeneous wireless network test-bed. The proposed AI framework enhances the average throughput by approximately 36%. However, the proposed framework is costly in terms of training time and memory usage.

The authors proposed a deep-reinforcement learning approach for SDN routing optimization. To evaluate the performance of the proposed DRL based routing model, the scalefree network topology of 14 nodes, and 21 full-duplex links, with uniform link capacities and average node degree of 3, and traffic intensity levels from 12.5% to 125% of the total network capacity. The trained DRL routing model can achieve similar configurations that of methods such as analytical optimization or local-search heuristic methods with minimal delays.

Another aspect of network management is interference management. Interference management often relays on algorithms such as WMMSE. This algorithm is costly as it uses matrix inversion, to solve the problem of numerical optimization in signal processing, the authors proposed to approximate the WMMSE used for interference management, which is has a central role in enabling Massive MIMO systems. The authors showed that SP optimization algorithms could be approximated by a finite-size neural network.

Information and Communication Technology (ICT) is responsible for 2% to 10% of the world energy consumption in 2007, and it is expected to continue to grow. Also, more than 80% of ICT is from radio access network (RAN), which is deployed to meet the peak traffic load and stays on it even that the load is light. Motivated by saving energy for

green communication, 5G specifications require that energy use should decrease to 10% percent of the traditional 4G/LTE networks. This objective can be achieved by reducing the power consumption of the base stations and mobile devices.

Many researchers investigated the use of deep learning theory to minimize the energy consumption in 5G wireless networks . For instance, the authors proposed a deep reinforcement learning-based Small cell base stations (SBSs) activation strategy to lower the energy consumption without comprising the quality of service. In particular, the SBS on/off switching problem is formulated into a Markov decision process and solved by actor-critic (AC) DRL.

Energy consumption of the network alongside the quality of service degradation and mode switching costs are the cost metrics in this study. The networks have two hidden layers with a number of neurons of 200 and 100, respectively. The model is trained, and the daily cost is the average of 20 days cost of 20 instances. The authors of data-driven base station sleeping operations through deep reinforcement learning.

Machine learning/ deep learning thus can help in building intelligent wireless networks that proactively predict the traffic and mobility of users and delivery services only when requested — subsequently reducing the power consumption in radio access networks. The authors developed a deep learning power control framework for energy efficiency maximization in wireless interference networks. Throughout the above-mentioned examples, deep learning can reduce energy consumption in 5G radio access networks.

Two prominent features of 5G are the network slicing and caching. The first allows operators to deliver different service types over the one network infrastructure. The latter predicts the content that users may request for efficient usage of the storage of the base station. Thus, the 5G requires accurate predictions of the needed resources in a slice and the future content of the users.

Several research works have investigated 5G resource provisioning and caching using the theory of machine learning/ deep learning. For example, the authors proposed X-LSTM to predict future usage to

manage 5G slicing. A metric called REVA is developed, and to forecast REVA the next 30 seconds with prediction intervals of 5 seconds.

The authors developed X-LSTM, which is built upon LSTM and ARIMA, which a popular statistical method. This methodology enables an improvement of X-LSTM over ARIMA and LSTM for X-LSTM outperformed the other time series models by 10%, 22%, and 31%, respectively. Also, X-LSTM results in more than 10% cost reduction per slice. The authors proposed a novel caching framework for offloading the back-haul and front-haul loads in a CRAN system. The proposed algorithm enables the prediction of the content request distribution of each user with limited information on the network state and user context.

Deep learning has also been investigated in cybersecurity of 5G wireless communications. For instance, the authors proposed an unmanned aerial vehicle (UAVs) aided 5G wireless communications with deep reinforcement learning against jamming attacks. The relay UAVs are used to establish the communication of legitimate nodes. To determine the optimal policy of the relay UAV, the authors addressed proposed a deep reinforcement learning. The methodology can restore the communication between the base station and the legitimate users, but several issues need to be addressed to enable these anti-jamming methods.

The authors investigated the robustness of deep learning in wireless communication systems against physical adversarial attacks. The author of proposed a machine learning model for power control for mmWave Massive MIMO against jamming attacks. The authors proposed a 5G cyber-defense architecture to identify cyber-threats in 5G wireless networks. This defense architecture uses deep learning to inspect the network traffic by extracting features from the traffic flow. In The integration of AI in 5G wireless communication systems faces many challenges. Some of these challenges can be listed as follows:

1. **The reliability and speed trade-off:** The reliability of these techniques is far less than traditional techniques in wireless communications in solving some problems. For instance, deep learning can compete with LS and MMSE in wireless channel estimation in massive MIMO, but slow feedback characterizes these

techniques. Deep learning inference may elongate the system response time. This is because not most wireless devices have access to cloud computing, and even if it is the case, communication with cloud servers is going to introduce extra delays.

2. **The complexity:** Deep learning algorithms, in due course, need to be implemented in wireless devices. However, many wireless devices have limited memory and computing capabilities, which is not suitable for complex algorithms. The collection of large samples and training deep learning models takes considerable time, which is a significant impediment to deploy them on some wireless devices having limited power and storage. Also, some applications require real-time processing, and on-fly sampling and training often cannot be performed easily. In some cases, the higher the number of samples and the more significant the training time are, the higher the accuracy of recognition of the signal and network features is. Acquiring more samples and training the models for longer times incur slow feedback. Therefore, the deep learning models should be designed to achieve the best accuracy with fewer samples and within a short time.

3. **Data Collection and Cleansing:** It is necessary to collect data and build large comprehensive datasets to train AI models, and this task is not often easy to acquire because mobile service providers, for instance, cannot release these datasets, which contains confidential information about the users and can risk the violation of the privacy of their consumers. Also, even with transfer learning, which refers to use models trained on the previous dataset, it is necessary to adapt these models for specific networks and scenarios which require re-training of the models. All these reasons restrict the development of wireless AI

4. **Privacy:** Preserving the privacy of the users is the primary concern of mobile and service providers. One of the main challenges in wireless AI is how one can enable the training on a dataset belonging to users without sharing the input data and putting the personal information of users at risk. It is necessary to have a security approach to boost the integration of deep learning in wireless communications.

5. **Security:** The security of deep learning models itself in another challenge, as neural networks are prune to adversarial attacks. Attackers can affect the training process by injecting fake training datasets; such injection can lower the accuracy of the models and yield wrong design, which may affect the network performance. Research in the security of deep learning or machine learning, in general, remains shallow.

In order to ease the integration of deep learning, research efforts are needed in several directions. For instance, the acceleration of deep neural network alongside advanced parallel computing, faster algorithm, and cloud computing, distributed deep learning systems present an opportunity for 5G to build the intelligence in its systems to deliver high throughput and ultra-low latency. There have been some recent efforts in deep neural network acceleration .

The acceleration of deep neural network, can be at three levels: architecture level, computation level, and implementation level. At the architecture level methods can be used, including layer decomposition , pruning , projection , and knowledge distillation . At the implementation level, several characteristics can be explored such as advanced GPU and FPGA designs . Using deep learning acceleration methods can achieve lower the complexity of deep learning with small loss in the accuracy of these models. Combining these methods can reduce the number of parameters by more than 50%. Further exploration of the acceleration of these networks can have a huge impact on the adoption of this deep learning to build intelligence in 5G systems.

Another way to speed up the integration of deep learning theory is 5G wireless communication systems is data collection and cleansing as there are not many datasets available so researchers that can used to build and test their models. Efforts in this directions are highly needed to build systems that can generate dataset.

Future wireless communications are becoming increasingly complex with different radio access technologies, transmission backhauls, and network slices, and they play an important role in the emerging edge computing paradigm, which aims to reduce the wireless transmission latency between end-users and edge clouds. Deep learning techniques,

which have already demonstrated overwhelming advantages in a wide range of internet of things (IoT) applications, show significant promise for solving such complicated real-world scenarios.

Although the convergence of radio access networks and deep learning is still in the preliminary exploration stage, it has already attracted tremendous concern from both academia and industry. To address emerging theoretical and practical issues, ranging from basic concepts to research directions in future wireless networking applications and architectures, this chapter mainly reviews the latest research progress and major technological deployment of deep learning in the development of wireless communications. We highlight the intuitions and key technologies of deep learning-driven wireless communication from the aspects of end-to-end communication, signal detection, channel estimation and compression sensing, encoding and decoding, and security and privacy.

The guiding principle in communication system design is to decompose signal processing into chains with multiple independent blocks. Each independent block performs a well-defined and isolated function, such as source coding/decoding, channel coding/decoding, modulation, channel estimation and equalization . This kind of approach yields today's efficient, versatile, and controllable wireless communication systems.

However, it is unclear whether the optimization of individual processing blocks can achieve optimal end-to-end performance, while deep learning can realize theoretically. global optimal performance. Thus, deep learning has produced far-reaching significance for wireless communication systems and has shown promising performance improvements.

Deep learning-based signal detection is getting more and more popular. Unlike the conventional model-based detection algorithms that rely on the estimation of the instantaneous channel state information (CSI) for detection, the deep learning-based detection method does not require to know the underlying channel model or the knowledge of the CSI when the channel model is known . A sliding bidirectional recurrent neural network (SBRNN) was proposed in  for signal detection, where the

trained detector was robust to changing channel conditions, eliminating the requirement for instantaneous CSI estimation.

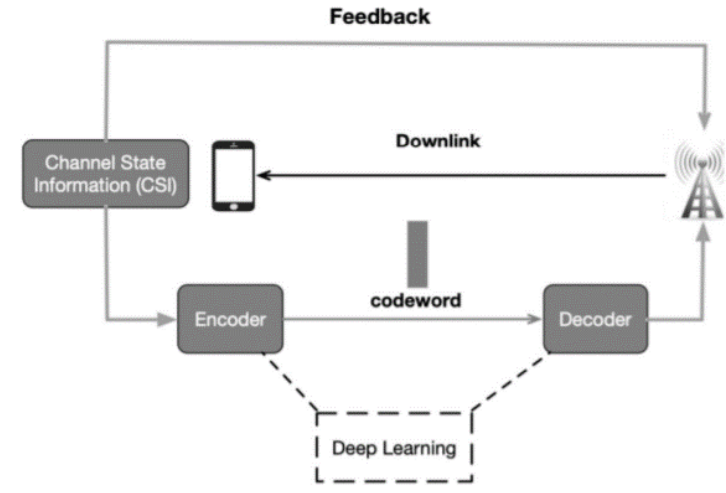
Unlike traditional orthogonal frequency-division multiplexing (OFDM) receivers that first estimate the CSI explicitly, and then the estimated CSI is used to detect or restore the transmitted symbols, the deep learningbased method in  estimated the CSI implicitly and then recovered the transmitted signals directly. The estimated CSI was to solve the problem that a large amount of training data and high training cost were required due to a large increase in the number of parameters caused by DNNs. Some recent works have suggested the use of DNNs in the context of MIMO detection and have developed model-driven deep learning networks for MIMO detection.

For example, a network specifically designed for MIMO communication can cope with time-varying channel in only one training phase. Instead of addressing a single fixed channel, a network obtained by unfolding the iterations of a projected gradient descent algorithm can handle multiple time-invariant and time-varying channels simultaneously in a single training phase . Deep learning-based networks as demonstrated in  can reach near-optimal detection performance, guaranteed accuracy and robustness with low and flexible computational complexity Channel estimation and compression sensing are key technologies for the real-time implementation of wireless communication systems. Channel estimation is the process of estimating the parameters of a certain channel model from the received data, while compression sensing is a technique to acquire and reconstruct sparse or compressible signals. Deep learning-based channel estimation and compression sensing methods have been suggested in several recent works .

To tackle the challenge of channel estimation when the receiver is equipped with a limited number of radio frequency (RF) chains in massive MIMO systems, a learned denoising-based approximate message passing (LDAMP) network was exploited in, where the channel structure can be learned and estimated from a large amount of training data. Experiment results demonstrated that the LDAMP network significantly outperforms state-of-theart compressed sensing-based algorithms. Motivated by the covariance matrix structure, a deep learning-based channel estimator was proposed in , where the estimated

channel vector was a conditional Gaussian random variable, and the covariance matrix was random. Assisted by CNN and the minimum mean squared error (MMSE) estimator, the proposed channel estimator can ensure the state-of-the-art accuracy of channel estimation at a very lower computational complexity.

The basic architecture of deep learning-based CSI feedback is shown. Recently, more and more researchers have focused on the benefits of CSI feedback that the transmitter can utilize it to precode the signals before the transmission, thus we can gain the improvement of MIMO systems. The precoding technique can help to realize the high quality of restoring signals and are widely adopted in wireless communication systems. By exploiting CSI, the MIMO system can substantially reduce multi-user (MU) interference and provide a multifold increase in cell throughput. In the network of frequency division duplex (FDD) or time division duplex (TDD), the receiver UE can estimate the downlink CSI and transmit it back to the BS once they obtain it and help BS to perform precoding for the next signal. BS can also obtain the uplink CSI to help rectify the transmission at UE.




The procedure of CSI feedback transmitting has drawn much attention, since high quality reconstructed CSI received by BS guarantees a good precoding, improving the stability and efficiency of the MIMO system. Inspired by traditional compressed sensing technologies, a new CNN-

based CSI sensing and recovery mechanism called CsiNet was proposed, which effectively used the feedback information of training samples to sense and recover CSI, and achieved the potential benefits of a massive MIMO. The encoder of CsiNet converted the original CSI matrix into a codebook using CNN, and then the decoder restored the received codebook to the original CSI signal using the fullyconnected network and refine networks.

To further improve the correctness of CSI feedback, a real-time long short-term memory (LSTM) based CSI feedback architecture named CsiNet-LSTM was proposed , where CNN and RNN are applied to extract the spatial and temporal correlation features of CSI, respectively. Using time-varying MIMO channel time correlation and structural features, CsiNet-LSTM can achieve a tradeoff between compression ratio, CSI reconstruction quality, and complexity. Compared to CsiNet, the CsiNet-LSTM network can trade time efficiency for CSI reconstruction quality. Further, the deep autoencoder-based CSI feedback in the frequency division duplex (FDD) massive MIMO system was modelled , which involved feedback transmission errors and delays.

As shown , a novel effective CSI sensing and recovery mechanism in the FDD MIMO system was proposed in our previous work , referred to as ConvlstmCsiNet, which takes advantage of the memory characteristic of RNN in modules of feature extraction, compression and decompression, respectively. Moreover, we adopt depthwise separable convolutions in feature recovery to reduce the size of the model and interact information between channels. The feature extraction module is also elaborately devised by studying decoupled spatio-temporal feature representations in different structures.

In digital communications, source coding and channel coding are typically required in data transmission. Deep learning methods have been suggested in some recent works that can be used to improve standard source decoding and solve the problem of high computational complexity in channel decoding. A DNN-based channel decoding method applied can directly realize the conversion from receiving codewords to information bits when considering the decoding part as a black box.

Although this method shows advantages in performance improvement, learning is constrained with exponential complexity. Therefore, it is neither fit for random codes, nor for codewords with long code lengths. The issue of joint source encoding and channel encoding of structured data over a noisy channel was addressed , a lower word error rate (WER) was achieved by developing deep learning-based encoders and decoders. This approach was optimal in minimizing end-to-end distortion where both the source and channel codes have arbitrarily large block lengths, however, it is limited in using a fixed length of information bits to encode sentences of different lengths.

Belief propagation (BP) algorithm can be combined with deep learning networks for channel decoding. Novel deep learning methods were proposed to improve the performance of the BP algorithm. It demonstrated that the neural BP decoder can offer a tradeoff between error-correction performance and implementation complexity, but can only learn a single codeword instead of an exponential number of codewords. Neural network decoding was only feasible for very short block lengths, since the training complexity of deep learning-based channel decoders scaled exponentially with the number of information bits and.

A deep learning polarization code decoding network with partitioned sub-blocks was proposed to improve its decoding performance for high-density parity check (HDPC) codes. By dividing the original codec into smaller sub-blocks, each of which can be independently encoded/decoded, it provided a promising solution to the dimensional problem. Furthermore, Liang et al. proposed an iterative channel decoding algorithm BPCNN, which combined CNN with a standard BP decoder to estimate information bits in a noisy environment. Security and privacy Due to the shared and broadcast nature of wireless medium, wireless communication systems are extremely vulnerable to attacks, counterfeiting and eavesdropping, and the security and privacy of wireless communications have received much attention. Moreover, wireless communication systems are becoming increasingly complex, and there is a close relationship between various modules of the system. Once a module is attacked, it will affect the operation of the entire wireless communication system.

Running AI functions on nearby edge servers or remote cloud servers is very vulnerable to security and AI data privacy issues. Thus, offloading AI learning models and collected data to external cloud servers for training and further processing may result in data loss due to the user's reluctancy of providing sensitive data such as location information. Many research efforts have focused on bridging DL and wireless security, including adversarial DL techniques, privacy Issues of DL solutions and DL hardening solutions, to meet critical privacy and security requirements in wireless communications.

Conventional wireless communication systems generally suffer from jamming attacks, while autoencoderbased end-to-end communication systems are extremely susceptible to physical adversarial attacks. Small disturbances can be easily designed and generated by attackers. New algorithms for making effective white-box and black-box attacks on a classifier (or transmitter) were designed . They demonstrated that physical adversarial attacks were more destructive in reducing the transmitter’s throughput and success ratio when compared to jamming attacks.

In addition, how to keep security and enhance the robustness of intelligent communication systems is still under discussion. Defense strategies in future communication systems are still immature and inefficient. Therefore, further research on the defense mechanisms of adversarial attacks and the security and robustness of deep learning-based wireless systems is very necessary. One possible defense mechanism is to train the autoencoder to have an antagonistic perturbation, which is a technique that enhances robustness, known as the adversarial training .

Adversarial deep learning is applied to launch an exploratory attack on cognitive radio transmissions. In a canonical wireless communication scenario with one transmitter, one receiver, one attacker, and some background traffic, even the transmitter’s algorithm is unknown to the attacker, it can still sense a channel, detect transmission feedback, apply a deep learning algorithm to build a reliable classifier, and effectively jam such transmissions. A defense strategy against an intelligent jamming attack on wireless communications was designed to successfully fool the attacker into making wrong predicts.

To avoid the inaccurate learned model due to interference of the adversary, one possible way is to use DNNs in conjunction with GANs for learning in adversarial radio frequency (RF) environments, which are capable of distinguishing between adversarial and trusted signals and sources. Open challenges This section discusses several open challenges of deep learning-driven wireless communications from the aspects of baseline and dataset, model compression and acceleration, CSI feedback and reconstruction, complex neural networks, training at different SNRs and fast learning.

Although DL-based CSI methods outperform much than the CS ones, the price of training cost remains high, which requires large quantities of channel estimates. Once the wireless environment changes significantly, a trained model still has to be retrained . In addition, a more able and efficient structure of DNN is needed. The design of CSI feedback link and precoding mode still remains an open issue that different MIMO systems should adopt their own appropriate designed CSI feedback link and precoding manner.

Furthermore, DL-based CSI feedback models are still immature when adopted in real massive MIMO systems and suffer constraints of realistic factors, e.g., time-varying channel with fading, SRS measurement period, channel capacity limitation, hardware or device configuration, channel estimation and signal interference in MU systems. These challenges may hinder the general applications temporarily and will be addressed by future DL-based models with a more exquisite and advanced architecture. Complex neural networks Due to the widely used baseband representations in wireless communication systems, data is generally processed in complex numbers, and most of the associated signal processing algorithms rely on phase rotation, complex conjugate, absolute values, and so on .

Therefore, neural networks have to run on complex values rather than real numbers. However, current deep learning libraries usually do not support complex processing. While complex neural networks may be easier to train and consume less memory, they do not provide any significant advantages in terms of performance. At present, we can only think of a complex number as a real number and an imaginary number. Complex neural networks that are suitable for wireless communication

models should be developed. Training at different SNRs Up to now, it is still not clear which signal-to-noise (SNR) ratio the deep learning model should be trained on. The ideal deep learning model should be applied to any SNR regardless of the SNR used for training or the range of SNR it is in. In fact, however, this is not the case.

The results of training deep learning models under certain SNR conditions are often not suitable for other SNR ranges . For example, training at lower SNRs does not reveal important structural features of wireless communication systems at higher SNRs, and similarly, training at higher SNRs can not reveal important structural features of wireless communication systems at lower SNRs. Training the deep learning model across different SNRs can also seriously affect the training time. In addition, how to construct an appropriate loss function, how to adjust parameters and data representation for wireless communication systems are still big problems that must be solved.

Fast learning For end-to-end training of wireless communication systems including encoders, channels, and decoders, a specific channel model is usually required. The trained model needs to be applied to its corresponding channel model, otherwise, mismatch problems will occur, which will cause severe degradation of system performance. In real-world scenarios, however, due to many environmental factors, the channel environment often changes at any time and place, e.g., the change of the movement speed and direction of user terminals, the change of the propagation medium, the change of the refractive scattering environment.

Once the channel environment changes, a large amount of training data is needed to retrain, which means that for different channel environments at each moment, such repeated training tasks need to be performed, which consumes resources and weakens the performance of the system. Retraining is required when the system configuration changes because the system model does not have a good generalization ability. Adaptation is done on a per-task basis and is specific to the channel model . Some changes in the channel environment may lead to a sharp decline in system performance.

Therefore, we need to seek systems with stronger generalization ability, in order to adapt to the changing channel environment. Potential opportunities This section mainly describes the profound potential opportunities and the promising research directions in wireless communications assisted by the rapid development of deep learning. Deep learning-driven CSI feedback in massive MIMO system Recent researches indicate that applying deep learning (DL) in MIMO systems to address the nonlinear problems or challenges can indeed boost the quality of CSI feedback compression.

Different from the traditional CSbased approaches, DL-based CSI methods adopt several neural network (NN) layers as an encoder replacing the CS model to compress CSI as well as a decoder to recover the original CSI, which can speed up the transmitting runtime nearly 100 times of CS ones. The structure of autoencoder-based MIMO systems is depicted , which only considers the downlink CSI feedback process, assuming that the feedback channel is perfect enough to transmit CSI with no impairments. In fact, a large part of the overload CSI serves redundant and the CSI matrix falls to sparse in the delay.

In order to remove the information redundancy, CNNs are applied here, which has the ability to eliminate the threshold of domain expertise since CNNs use hierarchical feature extraction, which can effectively extract information and obtain increasingly abstract correlations from the data while minimizing data preprocessing workload. We can consider both the issues of feedback delay and feedback errors. Assume that one signal is transmitted into n time slots due to the restriction of downlink bandwidth resource, thus demanding a n-length time series of CSI feedback estimation within a signal transmitting period and the SRS measurement period.

The time-varying channel is also under the condition of known overdue CSI or partial CSI characteristics, such as Doppler or beam-delay information. Furthermore, the feedback errors from MU interference brought by multiple UE at middle or high moving speed are also taken into account. When transmitting the compressed CSI feedback, the imperfections, e.g. additive white Gaussian noise (AWGN), in uplink CSI feedback channel would also bring feedback errors. The model is

trained to minimize the feedback errors via the minimum mean square error (MMSE) detector.

The architecture of DL-based autoencoder in CSI feedback compression is also advanced via taking the advantages of RNN's memory characteristic to deal with the feature extraction in time-varying channel, which can have an active effect on time correlation exploring and better performance on CSI recovery . Similarly, a DL-based autoencoder of CSI estimation method can be applied in this MIMO system, which is exposed to more practical restrictions. In the future, we can use DL methods of CSI feedback with time-varying channel in massive MU-MIMO system to improve the compression efficiency and speed up the transmitting process, as well as develop novel theoretical contributions and practical research related to the new technologies, analysis and applications with the help of CNN and RNN.

GAN-based Mobile data augmentation Mobile data typically comes from a variety of sources with various formats and exhibits complex correlations and heterogeneity. According to the mobile data, conventional machine learning tools require cumbersome feature engineering to make accurate inferences and decisions. Deep learning has eliminated the threshold of domain expertise because it uses hierarchical feature extraction, which can effectively extract information and obtain increasingly abstract correlations from the data while minimizing data pre-processing workload .

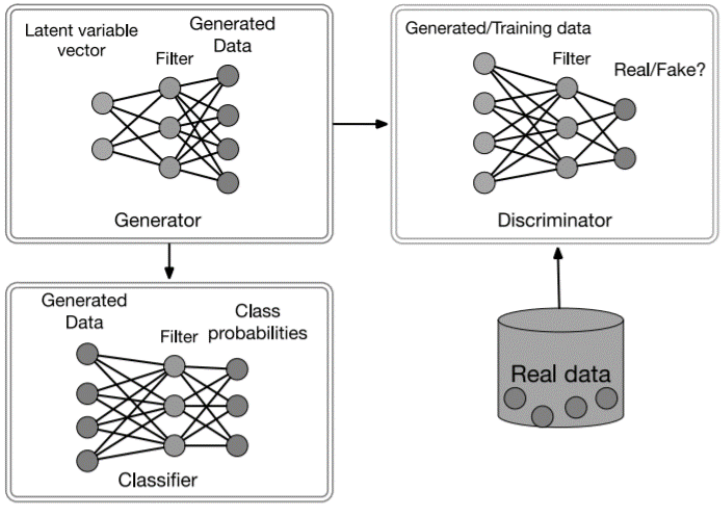
However, inefficiency in training time is an enormous challenge when applying learning algorithms in wireless systems. Traditional supervised learning methods, which learn a function that maps the input data to some desired output class label, is only effective when sufficient labeled data is available. On the contrary, generative models, e.g., GAN and variational autoencoder (VAE), can learn the joint probability of the input data and labels simultaneously via Bayes rule . Therefore, GANs and VAEs are well suitable for learning in wireless environments since most current mobile systems generate unlabeled or semi-labeled data.

GANs can be used to enhance the configuration of mobile and wireless networks and help address the growth of data volumes and algorithm-driven applications to satisfy the large data needs of DL algorithms.

GAN is a method that allows exploiting unlabeled data to learn useful patterns in an unsupervised manner. GANs can be further applied in B5G mobile and wireless networks, especially in dealing with heterogeneous data generated by mobile environments.

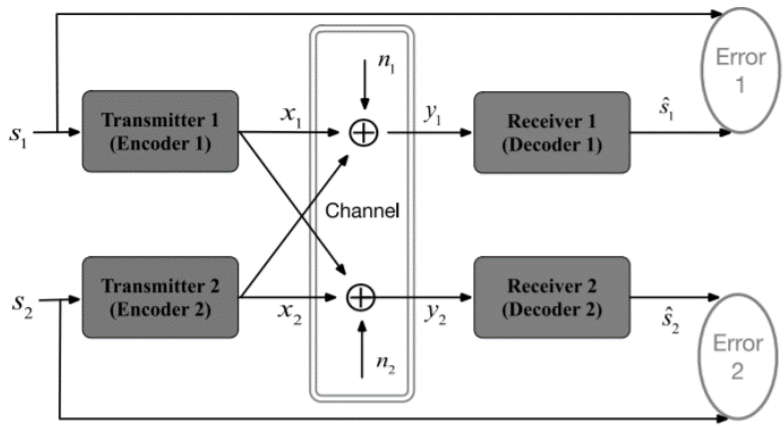
The GAN model consists of two neural networks that compete against each other. The generator network tries to generate samples that resemble the real data such that the discriminator cannot tell whether it is real or fake. After training the GAN, the output of the generator is fed to a classifier network during the inference phase. We can use GAN to generate real data according to previously collected real-world data. Furthermore, it can be used for path planning, trajectories analysis and mobility analysis.

Monitoring large-scale mobile traffic is, however, a complex and costly process that relies on dedicated probes, which have limited precision or coverage and gather tens of gigabytes of logs daily . Heterogeneous network traffic control is an enormous obstacle due to the highly dynamic nature of large-scale heterogeneous networks. As for a deep learning system, it has difficulty in characterizing the appropriate input and output patterns. GANs can be applied in resource management and parameter optimization to adapt to the changes in the wireless environment.



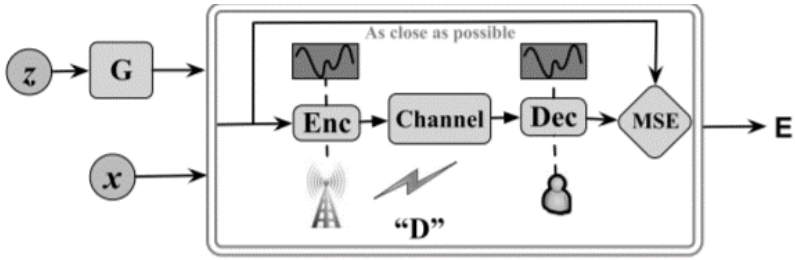
To make this happen, intelligent control of network traffic can be applied to infer finegrained mobile traffic patterns, from aggregate measurements collected by network probes. New loss functions are required to stabilize the adversarial model training process, and prevent model collapse or non-convergence problems. Further, data processing and augmentation procedure are required to handle the insufficiency of training data and prevent the neural network model from over-fitted. Deep learning-driven end-to-end communication The purpose of autoencoder is to make the input and the output as similar as possible, which is achieved by performing backpropagation of the error and continuing optimization after each output.

Similarly, a simple wireless communication system consists of a transmitter (encoder), a receiver (decoder) through a channel, and an abundant of physical layer transmission technologies can be adopted in the wireless communication process. A communication system over an additive white gaussian noise (AWGN) or Rayleigh fading channel can be represented as a particular type of autoencoder. The purpose of wireless communication is to make the output signal and the input signal as similar as possible.

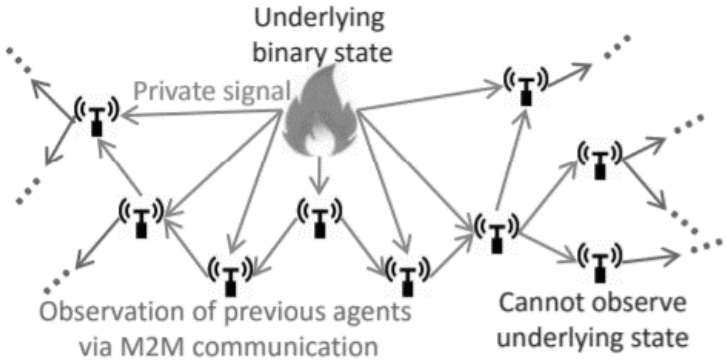



However, how to adapt an end-to-end communications system trained on a statistical model to a real-world implementation remains an open question.we can extend the above single channel model to two or more channels, where multiple transmitter and multiple receivers are competing for the channel capacity. As soon as some of the transmitters

and receivers are non-cooperative, adversarial training strategies such as GANs could be adopted. We can perform joint optimization for common or individual performance metrics such as block error rate (BLER).




In real-world scenarios, it is not worthwhile to perform multi-tasks training from scratch just because of different channel models, because these tasks are closely related, they share the same encoder and decoder network structure, and their parameter changes are only affected by the channel model. Training from scratch is under the assumption that such tasks are completely independent and cannot make full use of the connections, resulting in many repetitive and redundant training steps, however, it is not true. Meta-learning, or learning to learn , that is, to make the model a learner. It learns a priori knowledge in multitasking and then quickly applies it to the learning of new tasks, so that fast learning and few-shot learning can be realized.



Meta-learning provides a way to perform multitask learning and optimizes the system parameters toward a common gradient descent direction during training, thereby achieving the optimal generalization ability and reduced training data and/or time complexity. In the meantime, when a new task arrives, the system can train on a few rounds of iterative (or even one round of iterative) with very little training data, so that the parameters can be dynamically fine-tuned on the basis of the original learning model to adapt to the new channel model, where the dynamic parameter tuning is possible.

Thus, metalearning can be implemented for end-to-end learning of encoder and decoder with unknown or changing wireless channels, and it outperforms conventional training and joint training in wireless communication systems . A specific example of meta-training methods known as model agnostic meta-learning (MAML). Its core idea is to find a common initialization point that allows for a quick adaptation towards the optimal performance on the new task.

MAML updates parameters through one or more stochastic gradient descent (SGD) steps, which are calculated using only a small amount of data from the new task. Therefore, instead of training a common system model for all channel models, we can apply MAML to find a common initialization vector so that it supports fast training on any channel.

While emerging wireless applications require massive devices with real-time communication, computation, management and control, the growing complexity of wireless communications and networking has made monitoring the multitude of elements intractable.

As a result, embedding versatile machine intelligence into future wireless systems has aroused widespread concern in academia and industry. This trend is reflected in machine learning-based intelligent solutions, where a natural step is to learn optimal decisions in a proactive manner.

Based on network measurement and user behavior data, a variety of learning techniques, such as deep learning, transfer learning and reinforcement learning play a significant role in the wireless networking area. Artificial intelligence and machine learning facilitate complicated wireless scenarios analysis and prediction, and thus to make an optimal decision. We hope to incorporate artificial intelligence and machine

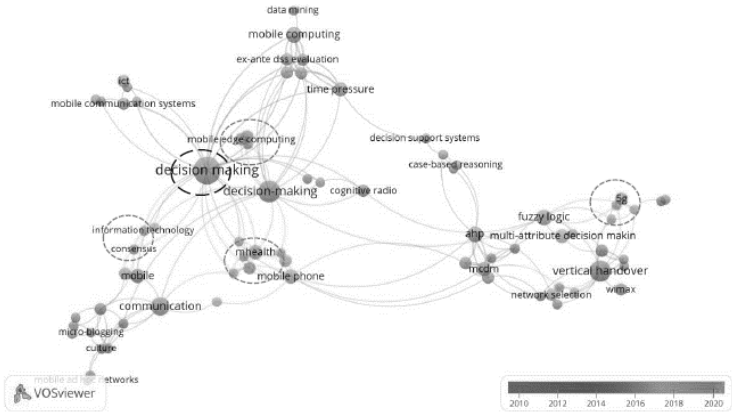
learning algorithms into wireless communications and networking systems, aimed at improving QoS/QoE and make the systems smart, intelligent, and efficient

Artificial intelligence will have an essential role in managing big data as advanced data analytics and organizing various communication devices in the future of mobile or wireless networks. In short, Xhang et al.stated that the mobile intelligence system should be self-adaptive, self-aware, proactive, and prescriptive. On the other hand, The infrastructure of mobile communication needs to be adaptive to diversified services and efficient and reliable, such as improving the performance of mobile broadband, minimize the peak-to-average power ratio (PAPR) [,improving orthogonal frequency division multiple access (OFDM) , improved link quality . In the 5G mobile communication system, the challenges will be appeared because of the huge nodes and mobile devices with fast data interchange and communication . It was explained by Kibria et al. , who have overviewed data analytics, Machine learning, and AI in network communication.

It supposed that the network management was and would be more complex within the new mobile communication generation network. Banupriya et al. forecast that the traffic will rise to 1000 times in 5G mobile communication according to mobile end-user data speed and growth. Hence, traditional network management and techniques are not supported in the next generation of mobile communication .

Next, the traffic control issues are still open to topic research because the previous researchers still focused on the core network issue on the network layer side, such as applied AI on the routing problem . However, few AI techniques are used for traffic control according to user experienced recommendations on the application and the semantic layers. Another challenge is how to apply AI to the next-generation mobile communication system. For example, in 5G, there are three types of challenges as hoe to provide broadband multimedia based on user experiences (enhanced mobile broadband(eMBB)), tactile internet application (ultra-reliable low latency service (URLLC)), and how to connect the amount of mobile device with real-time interconnection (Massive machine-type communications (mMTC)) .

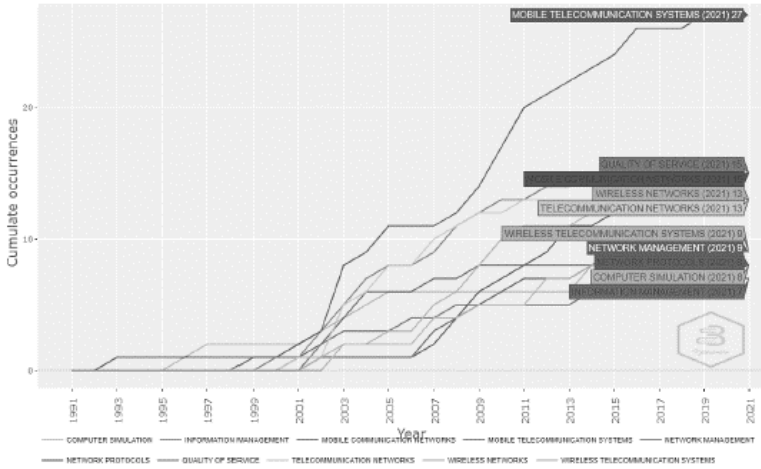
To strengthen the evidence on research trends regarding "decision making" in mobile communication, data from scopus.com was used with a total of 188 articles. The keywords of the articles were analyzed based on using the VOSViewer application. The type of analysis used is co-occurrence with the author-to-words analysis unit. The minimum number of occurrences of a keyword is 2 of the 625 keywords, 82 meet the threshold. , it can be seen the analysis of the relationship between variable keywords, the circle shows the number of keywords used, the color shows the renewal of the keywords, and the line shows the relationship of the keywords.




The "decision making" keyword becomes a motor theme that has a relationship with other keywords. Future research needs to pay attention to the aspect of the relationship between the keyword "Decision making" in Mobile Communication and the keywords circled in red with the keyword dot color in yellow. The brighter the dot color on keywords indicates the renewal of the keyword trend based on the article year.

An example of an application on network management in wireless communication is routing, a topic in communications. Some studies have already implemented AI for this topic. For instance, is a neural network is applied to realize self-configuration and self-optimization for both the radio resource and routing . In another research, Machine learning methods have been used for tackling different types of routing problems in the past. It contained shortest path routing, adaptive routing, and

multicasting routing . Other networks management in Wireless communication is to monitor various network activities and detect anomalies, i.e., events that deviate from the current network behavior. AI also has been used for predicting traffic in a communication network.




AI technologies can minimize traditional interventions in network traffic management and enable reliability, more adaptive systems, and better network performance. keyword "mobile telecommunication systems" has been a word that often appears in the articles. After that, then "quality of service" is appeared in 2000 and has grown to this day. To sum up, "mobile telecommunication systems" theme is being the most popular keyword accompanied by other trends such as "mobile communication networks", "quality of service", "telecommunication networks", "wireless networks", "network management", "wireless telecommunication systems", "computer simulation", "network protocols", and "information management"

# Chapter - 17

# Security Threads In Artificial Intelligence

## AI-Enabled Information Operations:

AI and associated technologies will increase the magnitude, precision, and persistence of adversarial information operations. AI exacerbates the problem of malign information in three ways:

### Message

AI can produce original text-based content and manipulate images, audio, and video, including through generative adversarial network (GAN)-enabled and reinforcement learning (RL) deep fakes that will be very difficult to distinguish from authentic message.

### Audience

AI can construct profiles of individuals' preferences, behaviors, and beliefs to target specific audiences with specific messages.

### Medium

AI can be embedded within platforms, such as through ranking algorithms, to proliferate malign information

Malware in the AI era will be able to mutate into thousands of different forms once it is lodged on a computer system. Such mutating polymorphic malware already accounts for more than 90% of malicious executable files.Deep RL tools can already find vulnerabilities, conceal malware, and attack selectively.

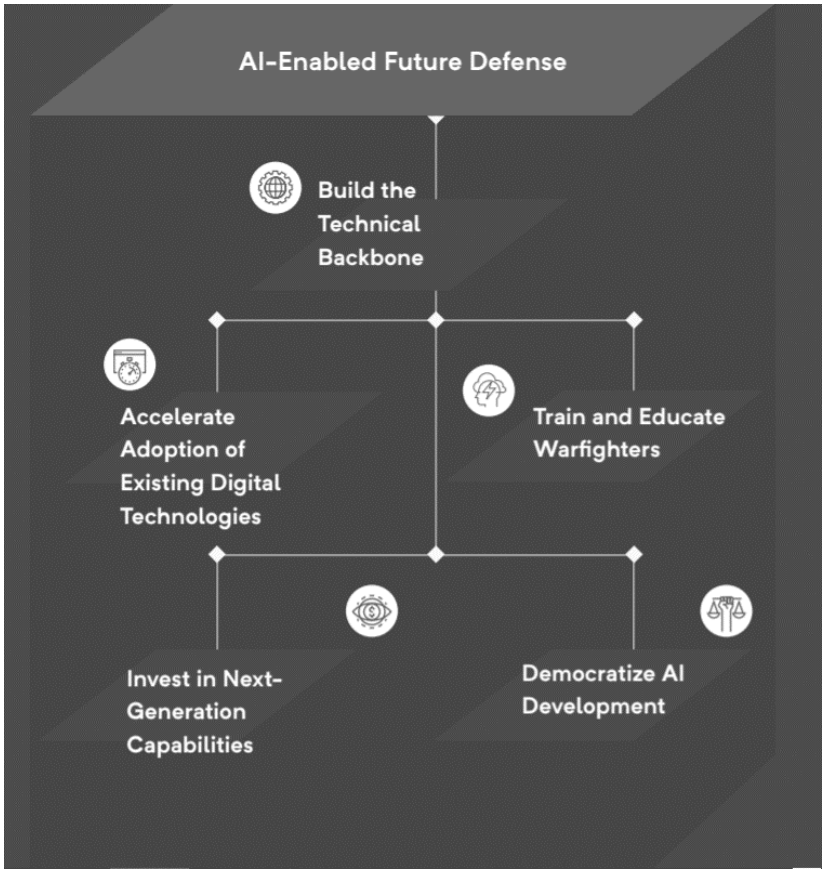
While it is uncertain which methods will dominate, there is a clear path for U.S. adversaries to transform the effectiveness of cyber attack and

espionage campaigns with an ensemble of new and old algorithmic means to automate, optimize, and inform attacks.This goes beyond AI-enhanced malware. Machine learning has current and potential applications across all the phases of cyber attack campaigns.

Develop and deploy AI-enabled defenses against cyber attacks. National security agencies need to acquire the sensors and instrumentation needed to train AI systems to detect and respond to threats on their networks. AI-enabled cyber defenses will also need large-scale, instrumented, and realistic testing, and they must be robust enough to withstand adversarial attacks. The defenses should be employed to expand machine speed information sharing, behavior-based anomaly detection, and malware mitigation across government networks.

To capitalize on these capabilities, the government should accelerate the establishment of a Joint Cyber Planning and Operations Center, modeled after the National Counterterrorism Center.The Center would serve as a centralized cyber intelligence sharing and collaboration unit with multi-agency jurisdiction and authorities to investigate threats, proactively support defensive mitigations, and coordinate responses. Biology is now programmable.

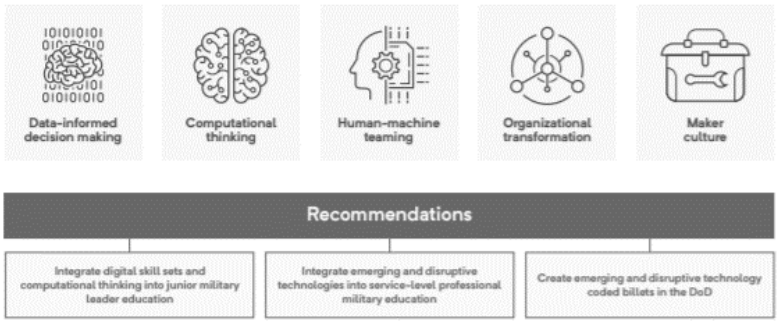
New technologies such as the gene editing tool CRISPR ushered in an era where humans are able to edit DNA.



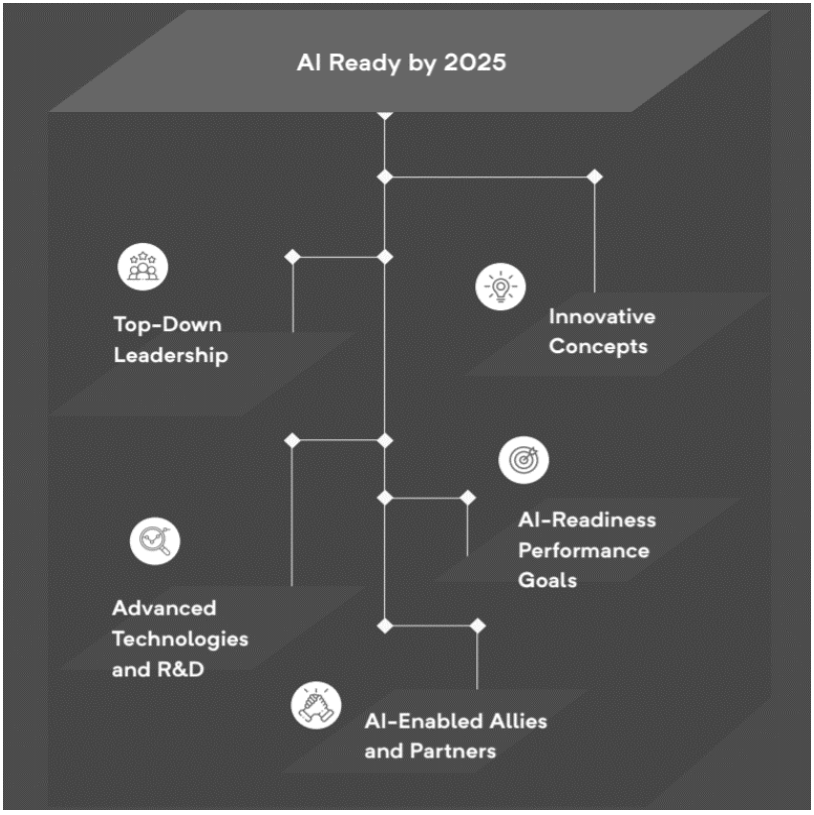

Combined with massive computing power and AI, innovations in biotechnology may provide novel solutions for mankind's most vexing challenges, including in health, food production, and environmental sustainability. Like other powerful technologies, however, applications of biotechnology can have a dark side. The COVID-19 pandemic reminded the world of the dangers of a highly contagious pathogen. AI may enable a pathogen to be specifically engineered for lethality or to target a genetic profile—the ultimate range and reach weapon. Also, AI, when applied to biology, could optimize for the physiological enhancement of human beings, including intelligence and physical attributes. To the extent that brain waves can be represented as a machine vision challenge for AI, the mysteries of the brain may be unlocked and programmed.

The obstacles to integrating AI are many. DoD has long been hardware-oriented toward ships, planes, and tanks. It is now trying to make the leap to a software-intensive enterprise. Spending remains concentrated on legacy systems designed for the industrial age and Cold War. Many Departmental processes still rely too much on PowerPoint and manually driven work streams. The data that is needed to fuel machine learning (ML) is currently stovepiped, messy, or often discarded.

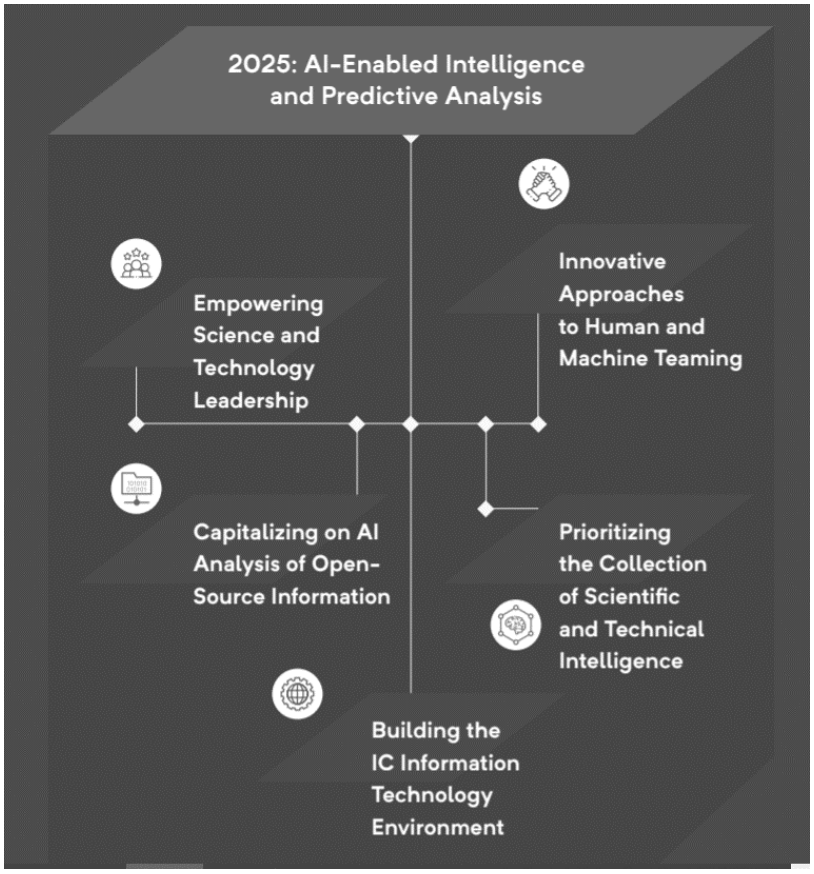
Platforms are disconnected. Acquisition, development, and fielding practices largely follow rigid, sequential processes, inhibiting early and continuous experimentation and testing critical for AI. Even promising AI programs have not yet delivered as hoped and often remain bound to proprietary software and data storage of commercial vendors. Steps such as building the cloud infrastructure necessary to scale AI applications proceed slowly. Datasharing agreements and software updates that take hours or days in industry turn into monthslong delays. Service members at every level lack the technical education and experience to employ AI.



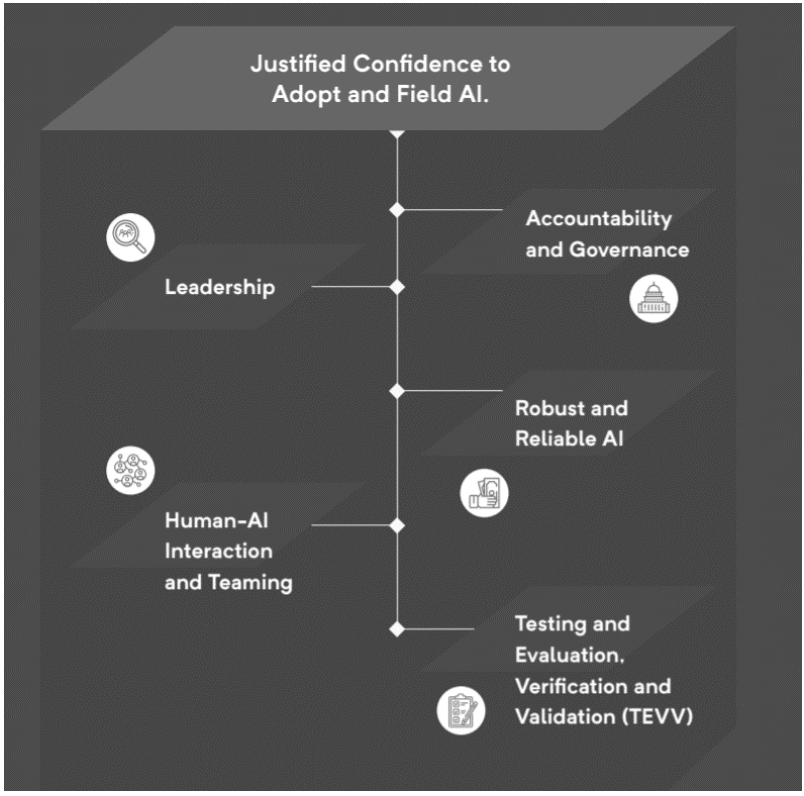

Meanwhile, bureaucracy hinders partnerships with technology firms and critical efforts to expand the National Security Innovation Base.The prospect of bureaucratic snarls deters companies from working with DoD; it is economically irrational for many startups to even try. Traditional defense companies will continue to play a central role in building and integrating large systems for AI-enabled warfare.However, even these contractors, who have the resources and expertise to navigate the system, face process and technical roadblocks that slow efforts to build and integrate AI systems.




The above Diagram is Vision in AI by 2025 for Security,R&D.This Diagram shows step by step process to be followed to achieve the vision by 2025.




Achieving acceptable AI performance often is linked to the decision to accept some level of risk. No technology works perfectly under all conditions. Risk calculus changes with circumstances. The variables and considerations that inform judgments to rely on AI will vary significantly across military, intelligence, homeland security, and law enforcement missions. In a high-threat environment like combat, in some cases it may be reasonable to employ a system offering some immediate military advantage, while recognizing that it might fail; in other cases, however, a reasonable commander might want the highest assurances of AI reliability before fielding when lives are at risk.

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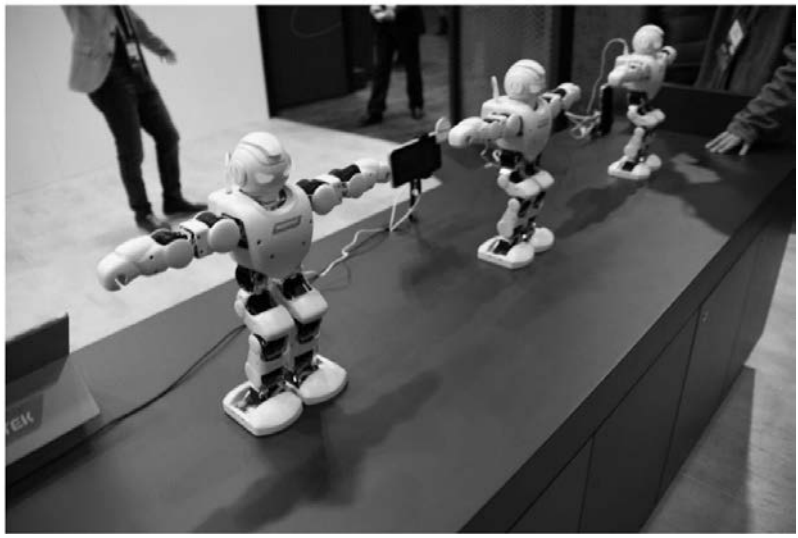
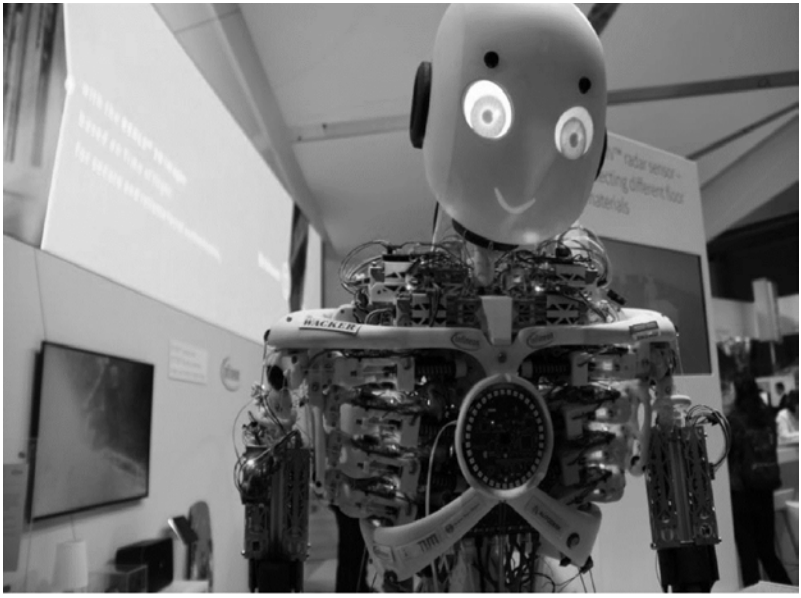
The below two pics are live AI Chatbot in industry laboratory for testing the Wireless Communication Technique.





Network Optimization is a common use of Artificial Intelligence in building different self-optimizing networks in the telecom industry. The networks are managed by different AI ideas and algorithms that predict and detect any kind of network abnormalities. Furthermore, Artificial Intelligence is used to optimize and configure various networks so that it is easy for end-users to leverage the advantage of stable network

performance. The telecommunication industry is willing to actively invest in Artificial Intelligence for network infrastructure. More than 63.5% of the telecom industry is using Artificial Intelligence for effective network infrastructure.

Conversational assistance and chatbots are the best trends that have made a huge impact in the telecommunication industry. Artificial Intelligence is completely leveraging the power of AI ideas in implementing chatbots and virtual assistants for handling customers and offering better support in an automated manner. Using AI-enabled chatbots and virtual assistants, businesses can deliver round-the-clock support and assistance to customers without any waiting time.

Artificial Intelligence-enabled predictive analytics is helping the telecom industries to offer better service and products to customers using relevant data. Sophisticated AI algorithms and machine learning is used in telecom Industries to predict future results. The managers and operators can utilize the potential of data-driven facts, insight which helps in decision making. It reduces the problems with hardware, cell towers, and power lines.

The telecommunication industry includes threats regarding scams and frauds every day. Machine Learning and Artificial Intelligence algorithms are used to stop any kind of fraudulent activities taking place that is not relevant and authorized by the user. The alerts are notified to the customers as well as telecom operators in real-time. The recommendation engine is used in the telecom industry to depict users' behavior and pattern. It helps in predicting the customers' future decision-making based on past behavior.

This helps the telecommunication sector to recommend the right services and product range to its customers. By analyzing data it is easy to predict users' behavior to understand the fact that whether they will behave like other customers or not. This helps the business to design relevant plans and services in a customized manner.

Telecommunication sectors are witnessing a huge transformation from 3G, 4G, and now 5G connection to its customers. It is a challenge for telecom businesses to meet the changing users' requirements. Real-time

analytics with the helo of AI tools helps in creating the best user-centric concept of the particular service and product.