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AI-Driven Telecom System Optimization and 5G Network Management: Transforming Manufacturing and Enhancing Connectivity for Medical Devices and Financial Services

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Abstract

In this paper, a novel use case of the AI-driven self-organizing framework for 5G networks is presented, which is an application of a machine learning-based real-time telecom resources management. The problem considered in this work is the potential use of a federated learning approach for telecom self-organizing deep reinforcement learning systems, particularly for real resources management in online mode. Three options for possible AI-driven network management based on federated learning are proposed: 1) a supervised machine learning model, trained on a telemetry database in the cloud, with model updates and downloads from the cloud to all base stations; 2) a distributed Q-learning model (network self-tuning) via a federated learning algorithm; 3) a reinforcement learning problem with shared experience with a local neural network. In the proposed approaches, advanced deep neural networks are capable of solving complex tasks, superior deep Q-learning combinations to current operations and maintenance layer systems and a significant improvement in the key performance indicator system of telecom operators.

Keywords: AI-driven framework, 5G Networks, Machine Learning, Real-Time Telecom Management, Federated Learning, Self-Organizing Networks, Deep Reinforcement Learning, Real Resources Management, Supervised Learning, Telemetry Database, Cloud-Based Model Updates, Distributed Q-learning, Network Self-Tuning, Reinforcement Learning, Shared Experience, Local Neural Networks, Deep Neural Networks, Deep Q-Learning, Key Performance Indicators, Telecom Operators.

1. Introduction

As the world becomes increasingly digital, data traffic between computing devices is skyrocketing. This particularly affects data traffic in networks based on the fifth generation of the cellular mobile communication standard. The fast growth of global mobile data traffic creates challenges for mobile operators who need to strengthen and extend their telecommunications networks. Moreover, accelerating the development of various mobile applications related to M2M services or automotive innovations calls for significant changes in the network's management processes. AI-driven methods and algorithms can help to solve these problems.

Telecommunication networks are becoming increasingly complex and difficult to manage and optimize. Their growth and development are constantly stimulated by the increase in data traffic. Over the past few years, the rapid growth of mobile data has led to a significant increase in global mobile data traffic. Shortly, thanks to the influence of the fifth generation of cellular mobile communication standards and the success of sophisticated smartphones and related ecosystems, mobile data traffic will continue to increase dynamically and accelerate the transfer of content between mobile devices.

1.1. Core Framework Components

From a long-term perspective, the sphere of large-scale operation of smart communications based on AI technologies should ensure the optimized functioning of the innovative 5G networks under construction and the following sixth generation of telecommunications. The development of AI systems and 5G networks should be based on a reasonable balance: the evolution of the structure of the management system should ensure the evolution of the structure of the new generation of networks, and vice versa. In this context, AI-driven network management is the way to manage the evolution of network potential at any given point in time.

Decades of AI development have enabled the continuous evolution of system optimization methods from linear

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programming through expert systems, fuzzy logic, and neural networks to more recent methods, such as Bayesian networks, genetic algorithms, ant algorithms, reinforcement learning, etc. Each of these methods has certain advantages; most of them have certain disadvantages and limitations. Therefore, the use of a wide set of existing methods and a combination of these methods is extremely useful and provides a competitive advantage. Currently, deep learning methods, which are a specialized branch of neural network technology, are of particular importance, having achieved significant success in several applications. The text presents models and tools based on the best achievements of AI technologies with the addition of several novel approaches to the problem of large-scale optimization of telecommunication systems and 5G network management.

2. Understanding AI in Telecom

Most AI-based systems operate on a pipeline driven by multiple deep neural networks, where each neural network is responsible for a specific task. For the same model, it may also have multiple functions simultaneously. For instance, an object detection model may return the detected object's label, confidence score, and bounding box coordinates. An AI algorithm also needs significant data and computing infrastructure. In telecom system optimization, most of the AI tasks can be broadly classified into the categories of network and subscriber. Most functional elements of the AI model, including the machine learning pipeline and feature selection to check the accuracy of output results, are shown below. For the network quality classification outputs, the single output function indicates the network quality classification task, while for the score to a policy function, the multiple outputs indicate that such a function takes both network location as well as a certain policy or rule as input to result in a score. Deep network models can accurately predict network status for early identification of problems and well-timed network upgrades.

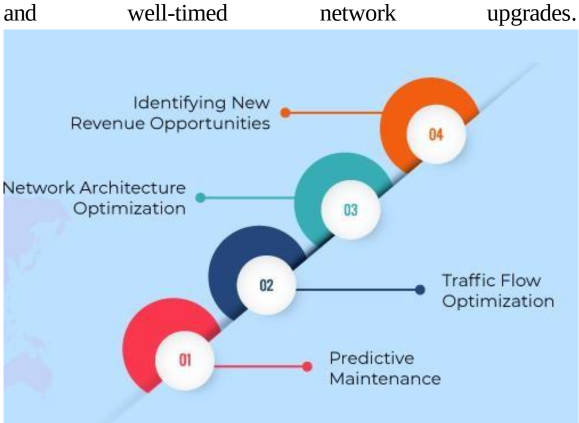

Fig 1 : AI in Telecommunications

The increased popularity of the use of AI for network traffic management is because some complex relationships among input features cannot be easily captured by traditional statistical models. A wide variety of AI models can generally handle huge dimensional networks, and the deep learning approach has the potential for the extraction of complex and time-varying structures and patterns of network traffic. In AI technology, optimization aims at identifying the most cost-effective allocation of capacity for the network under certain constraints, such as QoS requirements and selected routing and pricing strategies. Telecom operators, equipment vendors, and research partners collaborate to solve a variety of complex network problems. In general, as telecommunication network infrastructure is expensive and cannot be instantaneously deployed, there are increasing demands to make optimal use of the existing network resources. In this case, machine learning algorithms serve as a valuable tool to optimize the operation and management of these infrastructures by automating decision-making. With the exponentially increasing demand for the seamless provision of diversified services, the optimization of telecommunication network infrastructures has become increasingly important.

2.1. Definition and Scope of AI in Telecom

Today's telecom network industry is facing significant challenges such as soft revenue, rapid traffic growth, user experience demand, network complexity, and operability, lacking agility, and the requirement of deployment by all sectors in the digital environment. A quick, smart, and accurate fully automated AI is an efficient tool for the problem of self-determination in the telecom network industry to counteract these challenges. Despite the limitations of AI itself in different applications, the partnership of this intelligent system with subject matter knowledge and resourceful data management, applicable to a wide range, already shows promising results and potential. The advancement of AI, including supervised learning, unsupervised learning, transfer learning, domain adaptation, semi-supervised learning, and other related cutting-edge topics, are key drivers that can significantly help the telecom industry work towards its long-term goals by raising the bar at the business level.

An AI-based three-layer architecture framework shows a different abstraction level in a telecom network environment. Although several technologies provided in the hardware computing system and point cloud are AI-relevant, the adaptive two-level AI algorithm and the tangible physical entities in information systems utilize it, they cannot represent AI itself. The proposed AI two-level structured optimization ideas and other AI-enabled network management algorithms can be used in the management and optimization areas of the telecom network, which include

5G. Combined with practical field data, it can demonstrate the performance of the AI that telcos can interpret. This section summarizes layers in a telecom network information system and points out possibilities where AI tools can take action, also indicating research directions in an AI-driven telecom network management system.

2.2. Historical Context of AI in Telecommunications

For decades, improvements in telecommunications have been largely driven by two things: 1) the observation that the number of components in an integrated circuit doubles approximately every two years, leading to exponential growth in information technology, and 2) standardized telecommunications industry protocols, providing a clear framework for the development of physical and data link layers of the communication stack while allowing for competition and increased R&D investments in higher layers, such as signaling, supervision, and operation. Given the success of the old paradigm, there were very few incentives to invest in artificial intelligence (AI) in the telecommunications space, because it is usually assumed that high technology and standardized protocols bring functional decentralization, which in turn can achieve dramatic leaps in network performance that we have seen in the last 25 years. For instance, while most cell phones can trace their technological roots to the 1960s, the true era of 'always connected' mobile technology only really started in the early 2000s.

But interestingly, once the per-capita revenue from telecommunications started to flatten, thanks in part to the success of the model, and in others to the increased competition among a larger number of hackers, crackers, and cybercriminals, adapted from the PC world, as well as to the idea of secure telecommunications putting a significant financial burden on communication service providers, a strange thing happened. As the ability of technology to improve telecommunications flattened, the potential of connections between artificial intelligence and the telecommunications industry started to steepen, eventually leading to increased investments in the matrimony between the two fields in the form of concentration promoting company acquisitions, startup incubation, and investments, multiple joint research studies, and participation of numerous operators and service providers in shared industry research on the topic.

Equation 1 : Network Latency Optimization in 5G Systems

$$L = \frac{D}{B} + \frac{P}{C}$$

Where:

L = Network latency,

D = Data packet size,

B = Bandwidth,

P = Processing delay,

C = Computational capacity.

2.3. Current Trends in AI Technologies

Currently, AI technologies are achieving innovative advances, making them a top player in the IT domain. With automatic learning, a crucial part of the current AI movement is capable of interpreting context, which helps to improve both individual technology handling, such as vision and speech interpretation, and the emerging information built on large-scale datasets extracted from both supervised and unsupervised learning processes. This high adaptability, which is costly in terms of energy and hardware, has determined the existence of advanced cloud computing solutions that still need to disseminate actors across all technological fields to realize the full potential of AI. The availability of 5G and fiber-based communication infrastructures should propel the transition, finally creating a tightly knit tech scenario representing the foundation of Industry 4.0, which has a profound cultural and social impact. In the present context, the idea is to consider AI functions as a layer interposed between users, who will take advantage of advanced information services, and business decision-makers who need reliable and timely indications on business and technological behaviors. The two structural features of these computations, which also make these functions so effective, are CoW as a scalable engine embedded within AI computing infrastructures and an even more crucial dataset, which makes an AI-driven service possible. Considering the first point, CoW allows a broad and highly parallel vision of IT technology while allowing a unique ability to run a vast spectrum of specialized calculations within a central entity. This technology has been widely adopted, and today, the results and the opinions that leverage CoW and other cloud capabilities are becoming more and more desirable.

3. 5G Network Management

In contrast to 4G networks, 5G networks are complex and have a full range of air, terminal, access, backbone, and edge cloud capabilities that require precise control of the network, guaranteeing service bandwidth, delay, and terminal power consumption. Rapid user and device growth will only serve the needs of the Internet of Things through infrastructure

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capacity expansion. 5G operational capabilities and network management will be key to the sustainable development of operators and guaranteeing a differentiated experience for users. The optimization quality of the telecom system directly affects the user's experience, traffic monetization

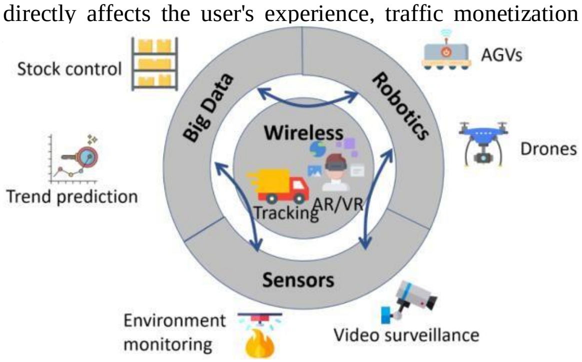

Fig 2 : Optimization of 5G Networks for Smart Logistics

5G network management covers site selection, investment planning, construction management, activation, network design, coverage optimization, and capacity adjustment. The organization has accumulated nearly 30 years of expertise in network management and integrated industry-leading AI technologies in 5G network management products to build SA, NSA, eMBB, URLLC, and mMTC network systems for 5G networks. AI provides automatic perception capabilities that are faster and more accurate in the face of an increasing volume of equipment abnormal alarms and improved network analysis capabilities to meet higher requirements for network visualization and analysis. With zoning optimization, single site optimization, massive MIMO weighing adjustment, multi-station collaboration, channel state perception, cross-band optimization, uplink enhancement, and fast and accurate high-quality NB-IoT network coverage experience deployment, it provides rapid and accurate high-quality experience deployment for massive MTC deployment business scenarios. With the characteristics of high precision and strong learning ability, machine learning algorithms can predict equipment abnormal trends and mine hidden network fault situations without using a large amount of data labeling, saving a large amount of manual data labeling resources and playing a significant role in improving network energy-saving efficiency.

3.1. Overview of 5G Technology

In fifth-generation (5G) technology, the research and development of several new accompanying technologies are performed, covering almost all levels of the telecommunications technology stack. Especially challenging are the design and development of new physical layer technologies and management of user mobility, energy consumption, and competition. The system's design complexity, together with a need for extremely fast and complex decisions, can only be accomplished by applying advanced artificial intelligence methods for network management, optimization, and system performance prediction, thus transforming 5G into a completely new AI-driven 5G-related domain. This AI-driven 5G domain introduces a very large challenge to the control plane due to the high system-wide complexity, and therefore, inter-level collaborative learning, transfer learning, and federated learning promise to be of paramount importance, where concordant policies will have to be developed and embedded.

The quest for higher throughput, low latency, and high reliability, while delivering a data rate capacity much higher than for 4G, and sharing the same frequency band with core public safety services applications, are a few of the main basic requirements in the 5G era. Regarding the users, both at the cell-edge and hot-spot areas, as well as for machine-type communication devices for interaction with the Internet of Things ecosystem, 5G presents revolutionary algorithms that ignore all structural and functional characteristics of the orthodox service packages, applications, and the corresponding commonplace rate. Increased cell density and the addition of new frequency bands and bandwidth aggregation are logical advancements for increased throughput. First, the active antenna system, the millimeter-wave band, and the advanced multiuser MIMO schemes will be introduced. Yet, future interactive object positions predict that the base station array aperture will grow and the channel bandwidth will dramatically increase in number. The active antenna system and the beamforming at the level of the user equipment open new opportunities and challenges for the RF hardware. The honeycomb paradigm, with a homogeneous deployment for cells, is getting challenged by the necessity of arbitrary network component placement. In 5G, the need for high-density networks also implies a gradual non-uniform lattice support, with loops and pico cells for a boost to MNOs for better bandwidth, energy saving, and low cost of ownership. The spectrum is also getting extended, not only in higher frequency, but also through regeneration and sharing of the sub-6 GHz bands, spectrum sharing, and dynamic spectrum composition.

3.2. Challenges in 5G Network Deployment

Given the potential for economic benefits and transforming industries such as transportation, manufacturing, and energy, the deployment of 5G is critical for growth and competitiveness. In an attempt to address all potential 5G-related issues, various research centers and companies around the world have outlined challenges that must be addressed to ensure the timely and successful deployment of 5G systems. These challenges include network densification, spectrum harmonization and coexistence,

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security, and architectural definition and integration of new mobile network features. In addition to these challenges, standardization bodies have identified specific requirements that are essential when deploying new 5G services. Other challenges arise from the integration and efficient use of new 5G capabilities and wireless terahertz communication technologies in existing non-terahertz radio access networks, whose essential features must be maintained and reused to ensure the continuity of existing services.

The current trend towards vertical integration according to the needs of each vertical leads to a significant increase in needs that cannot be easily implemented due to limited spectrum or cost issues. Therefore, it is critical to define who can best manage the 5G components, networks, and services. The idea of presenting end-to-end solutions from a given provider cannot lead to an open and fair use of 5G networks. More consideration will have to be given to the definition of opportunities for stakeholders in various industries to deliver high-value services, and how telecom companies can benefit from the deployment of 5G. Wireless operators cannot transform themselves into cloud-based operators to harness the resilience of embedded services, despite the significant investment in software to manage network slicing and run cloud-like applications in radio access networks. In addition, technical challenges will arise when scaling 5G networks from medium to high density, when HetNets will connect a large number of devices per unit of area.

3.3. AI Applications in 5G Network Management

With the advent of 5G, the network has increased in complexity, and the amount of data processing has also increased dramatically. Moreover, the issues that the network must solve and the services it provides are complex, diverse, and different. AI technologies can process data faster and more accurately than traditional rule-based methods and are highly efficient in solving complex network problems. Therefore, the application of AI technologies to manage 5G networks is an inevitable trend. This text focuses on emerging AI applications in 5G that are significantly different from traditional network architectures, including slice-specific, real-time, and intelligent issues. In particular, the capabilities and the issues that AI technologies focus on regarding the technical challenges, research directions, and network requirements are very different from traditional issues.

In the era of big data, machine learning has rapidly developed. Machine learning includes supervised learning, unsupervised learning, semi-supervised learning, reinforcement learning, etc. The ability of machine learning to collect, reshape, classify, and recognize massive data has led to significant progress in network optimization, security, and performance. In the era of 5G, the types of data, the quantity of data generated, and the devices with access to data have increased dramatically. The application of AI technologies, including machine learning, deep learning, and reinforcement learning, can process data faster and more accurately than traditional rule-based methods. This text includes both machine learning and deep learning, and we also focus on some issues and capabilities of AI technologies. The issues that AI technologies can solve are slicing, real-time, and intelligent issues, which are significantly different from those of traditional network architectures. Furthermore, AI adopts the idea of machine training, learning, and modeling on the actual network, so the research directions and the network requirements of AI-driven technologies in the 5G era are very different from those of machine learning. AI technologies can be considered a process of engineering. AI technologies include data collection, feature normalization and selection, model selection, model input, and output. Each stage is closely related to the characteristics and issues of AI. It is like the process of designing and building an intelligent telecom network.

4. Optimization Techniques for Telecom Systems

We differentiate between AI-driven optimization techniques and general telecommunications systems techniques. General telecommunications systems techniques are specific to the telecommunications sector and proactively propagate new trends, typically coupled with standardized algorithms or mechanisms to incorporate the new techniques into practical systems. AI-driven techniques, from an AI engineering point of view, can be relevant technologies for a variety of sectors, have the characteristic of minimizing the need for manual intervention, are not specific to the telecommunications sector, and can have a broader application across sectors. In some contexts, the terms data-driven and knowledge-driven are used but essentially have the same meaning.

Let us first define the general telecommunications systems techniques, which are specific for use in telecommunications outside the AI context. These include high-reliability complex systems, self-stabilizing algorithms for critical infrastructure, edge- vs. cloud-based algorithms, acceleration of forwarding rate, dynamic management for SDN-based cellular networks, network slicing in future mobile networks, voice traffic overload based on artificial neural networks, network abstraction for TCP-based manipulation, mapping compiler, personal mobility in near-future mobile networks, user data convergence for mobile networks, IP layer attacks, mobile network ecosystems, core network customization, and programmable network functions in virtualized flexible networks.

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4.1. Machine Learning Algorithms for Optimization

The overall network architecture is quite complex, and the network performance is an important issue for both the telecom operator and the users. A few studies propose AI-based optimization algorithms for telecom systems. The performance of these algorithms may highly depend on the type of AI used and the specific object of optimization. Machine learning and deep learning are some popular methods. They are applied to several problems with good performance. Most of the neural networks are based on supervised learning. The large amount of labeled data and the 'black box' limitation of deep learning methods are some open issues. However, the AI algorithm-based models are mainly used to predict network QoS, optimize power consumption, control the MIMO transmission modes, and resource allocations of the specific networks under specific scenarios. In general, the AI algorithm could be a good complement to the traditional optimization algorithms when the optimization object and the target network are clear. The AI algorithm might not have good performance when losses for general service loadings are a typical problem. More general AI algorithms are required. What is more important is that the performance of the AI models highly depends on the type of AI used and their applications. The performance of a well-trained AI model for one specific network might be significantly degraded for another different network. Some selected works demonstrate the applications of the AI model under some specific concerns, while few of them provide a general evaluation and discussion of the machine learning and deep learning algorithm mechanisms. Most open issues of the AI models are to define the label for the supervised training. The prevailing mechanism is to iteratively train the model using the predicted results as the label for the subsequent training. The model training is highly dependent on the label. Therefore, the performance of AI algorithms might be highly degraded if errors are easily propagated or accumulated from iteration to iteration. Since the performance of these AI models might highly depend on their tasks and applications, it is a main open issue how the AI models should be used and how to fully exploit the AI models to facilitate network optimization.

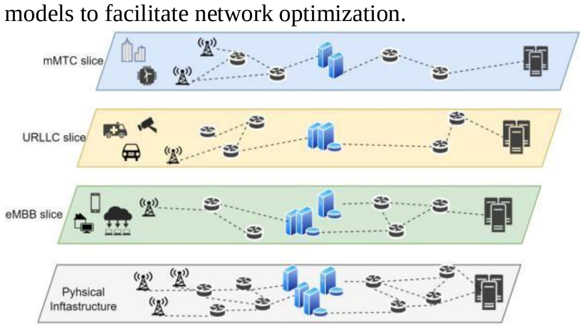

Fig 3 : Network Slicing and Machine Learning into Edge Networks

4.2. Predictive Analytics in Network Management

Predictive analytics is a data-driven science. It is a mix of AI and statistical models that use pattern recognition, machine learning, and data mining to identify probabilities, trends, or potential risks associated with unstructured and structured data. These models could predict future trends and outcomes. The models used in the predictive analysis process can be applied to many different types of business problems and can provide forecasts, trend analysis, risk assessment, and real-time predictions in many different fields, from customer segmentation and revenue assurance to fraud detection. Predictive analytics is widely implemented in telecom companies for many purposes. The data collected from the network can be used to predict customer churn, call duration, and types of calls offered.

In all the mentioned scenarios, the key idea is always the same: to use knowledge extracted from models created directly from the network's data to predict future outcomes, ultimately optimizing the company's returns. In the 5G world, all those predictions are important too. The key change is that more network model information is available, and that model accuracy and the volume of data that can be collected are increasing thanks to the use of AI and machine learning techniques. With the collection of additional data, it is now important to analyze and think up new ways to apply that data to improve the network quality of service over time and to deliver an infrastructure that can support new types of services. The approach now is much more proactive than it used to be: instead of detecting changes and fixing problems after they have emerged, the goal is to capture opportunities and fix issues before they affect the service to the user.

Equation 2 : AI-Based Resource Allocation for 5G Networks

$$R_{opt} = \arg\max \sum_{i=1}^{n} U(B_i, C_i, Q_i)$$

Where:

R_{opt} = Optimized resource allocation,

B_i = Available bandwidth for user i,

C_i = Computational resources,

Q_i = Quality of service for user i,

U = Utility function optimizing network performance.

4.3. Real-time Data Processing and Decision Making

A telecom system can produce much real-time data that will surpass the capabilities of data processing in the back office, such as the connection process for a network slice. Policy-driven real-time data analytics can provide opportunities to use the capabilities of communication systems efficiently. All data collection, processing, and decision-making can be

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enabled at the edge of the network to be completed within a span of less than 10 ms. In real-time telecom systems, AI algorithms can be used in an all-around way. AI-based network analytics and optimization can control every element and part of the network.

Modularization of policy rules and AI-designed hardware will need to be well-defined, high-level application programming interfaces for policy execution. The API should accept rule/policy sets, data inputs, and controlled data objects, return results, provide status feedback, and control requests and retrieval of supporting statistics captured by the device policy runner executing the rules. The small size of the flexible AI element also enables embedded security with multiple access control layers.

5. Impact on Manufacturing

Industrial players started using telecom infrastructure a long time ago, as networks of all mobile generations have always been excellent communication platforms. Nevertheless, the 5G technology – the latest generation of mobile communication – holds unprecedented potential for the manufacturing sector. It is destined to change the telco landscape beyond purely communications-related interests to offer industrial solutions that bring revenue to the telecom community. The reason for this is that the new 5G standard has been designed with the requirements of modern industrial processes in mind. By introducing changes in the area of 5G, Poland has been reinforcing its long-term policy of supporting the economic development of the country. The advanced 5G telecommunications technology is changing not only the telecommunications sector but also other sectors of the economy. Creating a network suited to the demands of diverse branches, not only improves telecommunications but also supports digitalization, increases innovativeness, generates additional revenues in many branches, and offers nearly unlimited opportunities for providing new services and innovative business models. The 5G technology's potential in those fields is enormous, yet the road to them leads through consistent preparation of the telecommunications system, both as a technological enterprise and as a business. The key issue in the context of network modernization is the necessary infrastructure development, as it is this aspect of the 5G technology that offers the chance to effect a lasting improvement in the telecommunications system.

5.1. AI and Automation in Manufacturing

This section contains some important use cases of AI and automation in manufacturing.

Quality control: AI is applied to perception issues in the course of advanced industrial activities. A novelty in the matter at hand is that it introduces the notion of different attributes and epochs and that it tries to distinguish the purposes of the research. Special attention is paid to the absence or presence of the signal between cases. Different architectures of artificial neural networks are designed for the fault detection task when changes in the data occur. The models are equipped with the capability of routing the disruptions to their nearest points. In this regard, each unit of the manufacturing equipment is described by one vector. Their ensemble builds a higher-dimensional space. The notion of time series comes into operation when increments between shortened windows are observed inside the operating grid.

5.2. Enhancing Supply Chain Management with 5G

With digitization and the deployment of 5G networks, digital connectivity has become a critical part of nearly every sector of the global economy, contributing to the rapid development of the information technology and telecommunication sectors. The management of spare part warehouses is critical to the telecommunications industry. Companies need to maintain sufficient stock levels to continuously provide high service levels to customers while maintaining a minimum stock level to avoid unnecessary inventory carrying costs. In this study, a novel AI optimization approach is proposed to support the supply chain inventory management process of a telecommunication company. With this approach, inventory control can be performed using AI algorithm outputs, which allow for better decisions and could automate, optimize, and thus drive the supply chain. The proposed approach optimizes supply chain inventory management systems at every node, including warehouses, by using a joint spatiotemporal behavior mining algorithm to construct the inventory simulation model results, which further optimize every node's optimal decision.

5G networks are expected to enable a variety of new revenue-generating business opportunities for industries such as agriculture, manufacturing, and health care. The management of the entire supply chain must be equipped with associated advanced management practices. Changes in today's highly networked, communication-savvy business environment require a new framework for the understanding and practice of telecom supply chain management. Today, telecom companies must always have optimal control of their service through access metrics such as service activation date, and network proximity, and determine the right service choice at the right time. They serve millions of subscribers through a range of services and options. However, as competitors drive businesses to deliver continuously improving levels of service provision for the user, we also expect high-quality options to be developed specifically for our preferences, such as better pricing. In the various processes of this management, machine learning, demand forecasting, data mining, statistical estimation, algorithm composition, and optimization play key roles in providing customers with optimal service levels and precise revenue estimation.

5.3. Case Studies: AI-Driven Manufacturing Solutions

AI technology is revolutionizing the field of systems and manufacturing across the world. Confronted with a volatile, uncertain, complex, and ambiguous business environment, one of the ways to sustain competitiveness in the manufacturing sector consists of keeping its operational systems efficient and effective. Accurate operational system outcomes, such as high-quality products and services, short lead times, and fast throughputs, are optimized by performing system and process optimizations based on reliable and timely high-quality key performance indicators. Regarding modern manufacturing systems, efforts need to be focused on the business intelligence relevant to their operational variables. This chapter discusses the four manufacturing workflow management solutions respectively tailored to actual manufacturing situations carried out by four manufacturing-related companies that apply real-time data collection techniques, cloud computing, big data analysis, machine learning, and other AI technologies. These implemented applications not only enhance the efficiency and effectiveness of production control but also increase the operational capabilities of manufacturing systems to prepare for the further development of the Industry 4.0 era. Furthermore, the solutions have been recognized by the system users, who have benefitted from the expected outcomes of the solutions. The success of the applications also indicates the reliability and effectiveness of AI technologies.

6. Enhancing Connectivity for Medical Devices

Implanted and wearable healthcare systems are gaining importance in the Internet of Bodies. These devices have the potential to support and enhance the elderly's or remote patients' lifestyles in the comfort of their familiar home environment and achieve continuous recording of patients' data. Body sensor networks and medical devices require an enhanced spectrum of reliable and efficient connectivity options to support the rapidly growing need for interconnectivity between devices, especially for use in medical healthcare applications. Communication networks have started to incorporate tailored features to enhance healthcare applications. However, these networks may experience mission-critical service disruptions due to network management issues or attacks. If unmitigated, these regular interruptions and exploits may lead to mission-critical and trust issues in healthcare systems.

Hence, we present an integrated, secure, and distributed artificial intelligence (AI) and network management platform to manage network resources and defend healthcare communications against jamming attacks. We address the jamming attack in the aerial communication channel interfering with the downlink reception in users' cell coverage area. Our proposed solution protects mission-critical data transfers and provides cell coverage area-dependent communication quality. Our AI models adapt the modulation of aerial communication based on existing channel conditions based on the cells' covered area. Our results indicate that our distributed AI-empowered intelligent reflect surface mitigates the jamming attack more efficiently and reliably than conventional static power control methods with a reduced signal-to-interference-noise

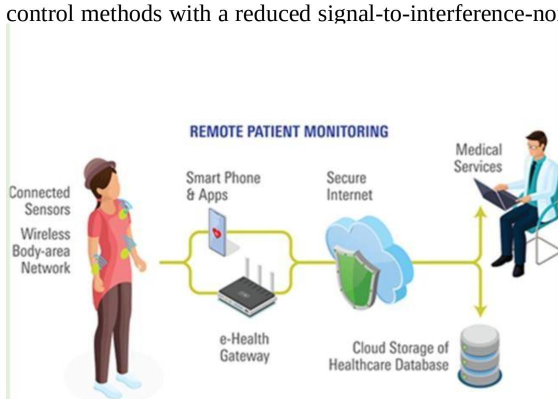

Fig 4 : 5G Technology in Healthcare and Wearable Devices

6.1. Importance of Connectivity in Healthcare

The increasing number of connected medical devices and systems has created an enormous strain on legacy networks, forcing healthcare administrators to consider more sophisticated and faster ways of delivering and retaining medical data. All medical and patient data require timely and reliable transport between endpoints, as the accuracy and speed of diagnosis are critical factors in patient care. The use of telemedicine, a collection of means or methods for enhancing healthcare delivery, public health, and health education using telecommunications, has accelerated to satisfy the demand for healthcare services, improve patient outcomes, and reduce costs; therefore, the ability to share imaging data is critical. Diagnostic medical imaging has surpassed all other technologies in its contribution to healthcare costs, providing a major performance challenge for hospitals considering moving ultrasound or MRI services off-site. Similarly, digitizing printed images, which required that slices be physically transferred from generation in CAT scanners or MRI scanners to display at geographically remote radiologists' workstations, has been surpassed by the

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explosive growth in the creation of digital radiography and x-ray angiography.

6.2. AI-Enabled Medical Device Management

This section focuses on a novel management model for AI-driven medical devices in the industrial 5G network. The proposed AI-enabled management framework with representative reasoning and collaboration modules is introduced and further supported by chosen optimization algorithms. To put theory into practice, we propose an evolutionary-driven task optimization model for the complex task coordination problem from reasoning modules across many ATSSs. We adopt genetic algorithms to find the global maximum of the formulated coordination model and accelerate the convergence speed. We then propose a reinforcement learning model to create a collaboration module across ATSSs, which can adapt quickly to the dynamic local environment and implement resource sharing. The simulation results show that our model can reduce the completion time significantly while ensuring the privacy and security of AI-driven medical devices. This work manages AI-enabler medical devices under the industrial 5G network and provides an essential theoretical foundation for future edge intelligence medical services in smart industry application scenarios.

Allow unlicensed low-power users to get dynamic access to the idle resources of an inoperative device. Such radio resource management under a payload-scheduling framework can improve the utility of the restore-enabled network. By employing SDR, the formulated problem can be solved efficiently in real-time. The numerical results confirm a significant performance gain in terms of resource utilization and outage probability. As a component, the BSTS framework can be integrated into specific applications and promote the development of different vertical industries. Consider the design problems of BSTSs, including the deployment, discovery, and provisioning of industrial data and the networking of AISs. Our contributions can be summarized as follows. First, we address a new industrial scenario for the AI-driven industrial world with multiple medical AI devices, including automated test and sorting systems.

6.3. Regulatory Considerations in Medical Connectivity

When implementing a new solution, healthcare organizations need to comply with a long list of regulations, including, but not limited to, special publications in the United States, as amended by relevant legislation, and principles on access, regulations, and the Medical Device Regulation. Telecommunications regulators are responsible for providing and regulating the ability to connect to health care systems and services. This unique relationship is critically important to make connectivity sustainable as healthcare moves into the future, where regulated innovation has great potential to dramatically reduce costs and improve outcomes.

The smartphone revolution has made it the most promising element for any telehealth or telecare solution. Smartphones are, however, made available by a continuously consolidating supply chain made up of a few large corporations for hardware and operating systems. These corporations may have direct business interests in the data and services that are transmitted over a healthcare solution. These structural conditions are highly likely to favor behavior by these corporations to drive the healthcare providers they connect to out of the communications business. This would leave those healthcare organizations captured within a complex web of regulatory constraints, while at the same time making them dependent on the implementation of a long list of specific procedures on the interests and business strategies of the corporation when it comes to patient data.

7. AI in Financial Services

Modern customer-oriented financial services providers work with vast arrays of data, and that data is often sensitive. AI techniques such as machine learning demonstrate a data collection, management, and interpretation capability that, if managed right, might optimize customer outcomes while managing risk, maximizing return on capital, and meeting increasing regulation. FinTech providers making use of AI in various aspects of financial services exist, both in new and established firms around the world. AI provides support through intelligent decision support to full intelligent process and task automation.

AI in financial services must be security-aware. Increased regulatory complexity, more sophisticated cyberattacks and bad actors, and positive customer data are all elements of the AI-powered financial services environment. This means that providers of AI-enhanced services and their customers must regulate and manage the necessary business and operational processes associated with the use of AI and data more rigorously than ever; be able to demonstrate regulatory compliance through regular audit and reporting; and provide increasing quality levels of service and protection to customers for sensitive data handling and management. However, the short-term evolution of AI in financial services is likely to lead to benefits realizable regardless of whether regulation is keeping up with frictions and uncertainties, with financial services businesses likely to continue to adopt or be acquired by AI-enabling businesses as a result.

7.1. Transforming Financial Transactions with AI

In today's fast-paced digital world, technologies are transforming payment systems to become innovative,

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transparent, and secure. Artificial intelligence is being used to develop machine learning algorithms fueled by large sets of data, including transaction histories, location data, web browsing, and feedback through social networks. With this data at their disposal, financial industries are now capable of identifying and predicting customers. Two broad themes describe the transformation of financial transactions through AI. Initially, large datasets that record customer transactions build enhanced capabilities for fraud detection and management. Secondly, by exploiting transaction-level data, businesses can develop scalable and highly personalized financial services that improve supply, price, and fairness to customers.

Presently, banks use large datasets to identify mundane shopping patterns that can be flagged early, usually through bonuses or commissions from retail. This is driven by millions of statistical forecasts that trade off the subject's history, the transaction received, the time of the transaction, and the customer's behaviors and experiences. For example, retail banks often monitor weblogs and others to ensure the insight bonus remittances at the end of the month. Some high-profit retail branches also refrain from offering currency on the first Mondays of the month to help eliminate excess cash that emerges in the run-up to bonus payments. Telephone banking, web, and mobile transactions introduce additional customer information that doesn't exist in traditional branch banking data. Banks are increasingly using customer transaction data to decide the subject's approach to the provision of banking services. They take customers' interactions through this channel with all products into account. For example, if a customer spends most of their money paying bills from another bank account and conducts a few other transactions, incentive approaches to the institution may encourage the switching of that account specifically, thus preserving the customer's profitable balance. Providing customers who demonstrate loyalty in the form of a balance rewarded with products or reduced fees can be highly attractive, entrenching customers in their first choice for core banking services.

7.2. Risk Management and Fraud Detection

The growing industry interest in big data technologies has given rise to immense volumes of data. At the same time, the growing capability of sophisticated computing systems has led to a steep growth in AI and machine learning technologies. Telecom enterprises have turned this industry trend into an opportunity for growth acceleration, new monetization opportunities, and cost optimization by building AI-driven systems for improving performance. The AI-driven data analytics engine can also use advanced analytics and machine learning to optimize telecom systems, making them more effective and intelligent and ultimately catalyzing new monetization opportunities. Such systems can also be used to effectively predict system failures and events whose duration is unpredictable, and hence reduce as much of the risk as possible.

This chapter outlines the recent work done in the area of AI-driven telecom system optimization and 5G network management. With a long history dating back to the mid-nineteenth century, the company has been through several years of sustained growth from the late 1980s onwards, during which time it expanded its operational footprint dramatically. With its increasing investment in 5G technologies, the company has been using AI-driven, data-driven 5G monitoring systems to optimize its various 5G system operations. Such AI-driven systems are capable of optimizing the administrative procedures that depend on predictive models and reducing the overall risk involved in network operations. In addition, an AI-driven data analytics engine can be built and used to take advantage of advancements in the sophistication and complexity of machine learning developed over the years. With increasing 5G implementations and migrations from 4G systems, it is clear that the telecom industry must use such advanced AI-driven, data-driven systems for its management and optimization.

7.3. Case Studies: AI Applications in Finance

The financial industry is one of the largest industries that apply AI, which can improve productivity and reduce costs. In this section, several AI applications are discussed in the areas of both services and manufacturing. The first case demonstrates the relevance of AI in driving customer relationship management, especially in private banking, and the opportunities that new technologies can provide, from user experience innovation to data intelligence, to improve models and advisory services. The second case is related to liquidity assessment, a core activity in today's banking risk management environment. Another application is related to claim assessment by AI, which represents an opportunity for banks to speed up the assessment and then submit the claim file to the regulator, reducing the allocation.

This study shows machine learning applied to claim assessment through text recognition of images, demonstrating how to leverage different image-based deep learning software components to build a functioning but simple machine learning pipeline for this particular application. Finally, we discuss the impact of machine learning on high-frequency trading and the importance of using explainable AI as a powerful tool to understand the behavior of financial systems by improving their predictive performance. AI is seeing more and more implementations in the financial industry today. Whether it is AI, deep learning, or machine learning, the financial world can analyze the financial markets and customer behavior by

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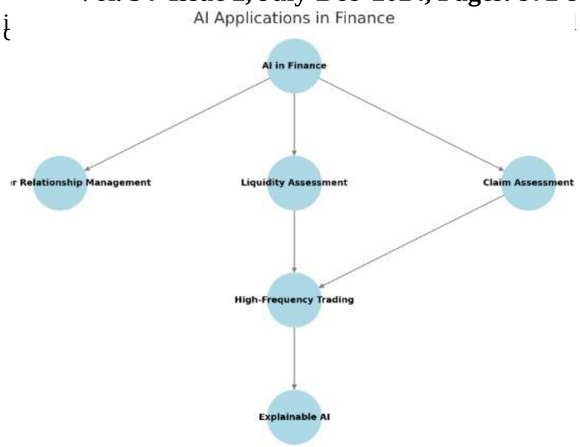

Fig 5 : AI Applications in Finance

8. Challenges and Limitations

Our extensive survey of the state-of-the-art AI/ML approaches for telecom system optimization and 5G network management has showcased a plethora of existing applications in the industry. However, we also noted several challenges and limitations in implementing AI/ML techniques for industry-scale deployment. This section presents two perspectives on the formidable challenges that practitioners may encounter in their quest to implement AI in 5G technology. The first perspective is from the angle of academia, where we posed very difficult research questions that still pose challenges both during the deployment of existing AI models and the development of new ones. The second perspective is from the practitioners' viewpoint, where we identified the practical limitations in deploying telecom service optimization models into live networks.

One of the main goals of this chapter is to inform the research community of these challenges to motivate more research endeavors from the academic and research domains. These considerations would enable better-designed systems that are directly influenced by real industry problems. Furthermore, we hold the strong belief that some of the advancements made by these joint efforts could significantly benefit both the research community and the telecommunications industry by allowing for the commercialization of innovative intelligent techniques that truly transform how network and service operations are modeled, automated, and optimized from end to end.

8.1. Data Privacy and Security Issues

A lot of research on the security and privacy aspects of Industry 4.0, data-driven and learning-based automation, and intelligent management systems of AR may be considered relatively mature. A security solution related to the smart industry, including secure multi-party computation, federated learning, differential privacy, as well as cryptographic protocols, is well understood and ready to be implemented at scale. However, for future telecom systems, especially for AI-driven network management, both the security and privacy solutions are still largely in the early stages of research. Although there are simple data-sharing use cases from the current major practitioners that have been shared in the industry, as expected, these are primarily proprietary solutions and do not disclose the development path or detailed working mechanisms of these security measures.

It is expected that the AI-driven operations of next-generation telecom and 5G network capability will include applications such as user experiences, HR, network optimization, security management, cognitive network design, closed-loop optimization, service scaling, dynamic network planning, implementation and optimization, real-time management and orchestration of vertical services, general machine learning operations, reasoning and policy execution, fault tolerance, real-time improvability, and policy control of AI training data, machines, and algorithms to test for fairness or bias. Set the appropriate privacy constraints, leakage penalties, and the related risk assessment of neural network decisions, AI model production, and black box decisions, as well as AI model integrations such as situational feedback, dependent data, and cyber-physical system data leakage behavior. Since most of the solutions are task-specific, they shall be taken as a trust indicator and a temporary implanted rule of professional commitment to the privacy and security of AI performance control of network operation to protect personal data security and respect privacy.

8.2. Integration with Legacy Systems

Most mobile operators face the dilemma that the development timeline of the 5G network and the growing number of value-added services require parallel maintenance of the legacy 2G/3G/4G network. Concerning a legacy telecom network and the associated OSS and BSS, and only a limited number of network elements being replaced by the new ultra-dense 5G network with V-RAN, we consider integrating the N-OMAS with the legacy radio network and an OSS that consists of the original legacy RAN optimizer and a rudimentary 5G optimizer that only performs the basic functions of best cell selection and user equipment association for the 5G case. The reasons for doing this are numerous. For one thing, while the new RAN optimizer achieves self-organizing, self-learning, and self-optimization through AI/ML algorithms and intelligence, the legacy RAN optimizer is rule-based and is not knowledgeable about the market and does not know the details about the traffic patterns addressed by the various

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services. Therefore, integration with legacy systems is a good route for new RAN intelligence to learn from legacy wisdom. On the other hand, the passing between N-OMAS and O-OMAS is necessary through an OSS in which the orchestration is done. N-OMAS can be seen as an advisor or a coach to O-OMAS, having to interoperate with a somewhat proportion of the operator's legacy policy. Since 5G presents radical changes in RAN front-haul, backhaul, and fronthaul, being able to work as a middleman between them, N-OMAS is responsible for orchestrating and operating everything together and provides a smooth migration to greenfield ultra-dense 5G evolution.

8.3. Scalability Concerns in AI Solutions

In the current AI paradigm, the main focus in training is the ability to build a model and run it in as powerful a computing environment as possible in the least amount of time. While that improves the quality of models that are presented to solve a particular problem at any given time, the amount of data available to train models is usually limited by the time available to collect and migrate datasets to a powerful environment. When dealing with real-world problems, this is further complicated by a need to comprehend real-world dynamics, made accessible by limited amounts of local data. Since the telecommunication industry is one of the most complex, specialized simulations may reproduce real-world phenomenological behavior but only up to a certain point, by shrinking the training scenarios of models. Scalability assimilates the complexity of real-world systems into these AI algorithms in an efficient way and enables them to interact with and complement each other.

Considering that general AI can learn different tasks and test data for these tasks can be rather diverse, a standalone deterministic procedure should be capable of transferring knowledge to an interaction module with data that becomes available at runtime. This module should have an open enough logic to reinforce or contradict any conflicting judgments with a short feedback time to keep the network operational. With those pieces in place, AI palettes leveraging scalability will be necessary to interconnect and constantly promote their learning together so that the network can handle the detrimental consequences of billions of diverse smart devices connected to the network, in terms of energy, security, privacy, and latency with an expected gain in coverage, capacity, and mobility.

9. Future Trends in AI and Telecom

As an enabler, AI will also continue to vitalize areas such as communications hardware, software, and systems in the telecom space. In this chapter, we will lay out a more detailed framework for the application of AI-driven technologies to networking communications. Then, the exploration of massive unstructured network controls from a functional perspective without the lever of the bottom layer will be considered. A comprehensive future outlook is provided, including artificial general intelligence. The birth of wireless innovation and technology is the driving force of communication development. The end of each era is also the dawn of a new era. At the edge of the 5G era, the glittering digital index continues to exaggerate the importance of known and unknown innovation panaceas in the future communications field, leaving many people regretful. Little is known.

AI operations have gradually become the mainstream in networking. Take 5G network optimization as an example, which gives an important potential direction and a good demonstration of the broad application of AI in wireless networks. Supervised learning, unsupervised learning, reinforcement learning, and transfer learning have long commercial application prospects in systematized network optimization for large-scale users and a variety of heterogeneous service requirements.

9.1. Emerging Technologies and Innovations

The intensified use of IoT services places high demands on transportation capabilities on the telecommunications infrastructure, at a time when the telecommunications industry is also involved in the development of 5G services based on 5G technology to support extreme broadband, URLLC, and mMTC. To cope with these demands, AI-driven systems have been widely deployed in telecommunications companies to optimize their infrastructure, which includes radio, transport, and core networks. The AI-driven systems automate processes applicable to planning and operation phases and contribute to the optimization of the network's total cost of ownership. They may use supervised, unsupervised, and reinforcement machine learning techniques to support the development of predictive, prescriptive, and reactive strategies. In this context, a taxonomy for the classification of current AI systems developed for the telecommunication sector is presented.

This chapter presents emerging technologies and innovations in data-driven automation for the promotion of efficiencies by telecommunications companies with the anticipation of either being applied to current issues or used in systems' short-term evolution. The research focuses on the implementation of AI-driven telecom systems designed to optimize radio, transport, and core networks. The improved capabilities of telecom systems are expected to contribute to a faster introduction of 5G technology and support the increased capacity and new use cases that will be requested by enhanced mobile broadband, ultra-reliable low latency communications, and massive machine-type communications. The implementation of AI-driven telecom

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systems requires the development of algorithmic optimization frameworks that are coupled with 5G performance simulators and 5G infrastructure demonstrators. The algorithms are trained and the results are verified using real network data. The chapter highlights the need for the development of suitable interfaces to permit machine learning-based algorithm input. This should be considered as a pathway for presenting the real-time updates libraries, for the types of data used to train the AI algorithms, for the constraints and KPIs to be implemented, and for the data storage formats.

Equation 3 : 5G-Enabled IoT Device Connectivity in Manufacturing and Healthcare

$$C_d = \frac{N_d}{B_{eff} \times S}$$

Where:

C_d = Connection density (devices per unit area),

N_d = Number of connected devices,

B_{eff} = Effective bandwidth per device,

S = Coverage area.

9.2. Predictions for AI in Telecom by 2030

There are several AI-driven telecom systems optimization use cases. Enhancing user experience and network quality with network optimization problem-solving is a broad topic. It starts with collecting network parameters and data to characterize the network, traffic, and environment in a meaningful way. Optimal network management helps optimize the return on assets and reduces the cost of service. Automated network management with AI-driven optimization can provide predictions and decisions on the network state to take actions and steer behavior to reach optimal conditions for better network performance, efficiency, stability, or robustness against possible degradations or breaking states. AI-driven methods help optimize service coverage over time and provide decisions for network resource allocation to enhance user experience, application performance, quality of service, network utilization, and reliability for several management functions and services in a more efficient and automated manner. With network sharing scenarios, AI-driven client-adaptive techniques, slicing, service chaining, and core network function automation, the AI-driven network optimization wish list is vast for a large number of use cases and services. Before closing this section, we provide some predictions for AI developments in the telecom sector and their potential revenues by 2030. Our predictions are based on both the trends observed in our detailed survey and our direct experiences. The three key aspects that will deeply impact telecom operators are: an accurate target evaluation and enhancement of the benefits of AI applications in network and service management; understanding AI capabilities to develop or apply the best-fit tactics and strategies for their own business; and the feasibility to design, develop, integrate, and maintain an effective AI model on telecom platforms, respecting privacy, security, ethical, and economic constraints with controlled costs. These three requirements will guide the AI platform's purchase, rental, lease, or as-a-service decisions that telecom managers will make. Managers will ponder what is better between building and customizing their model for solving specific problems, reinventing an already existing accurate model, or using widely available AI platforms for optimizing their actual p

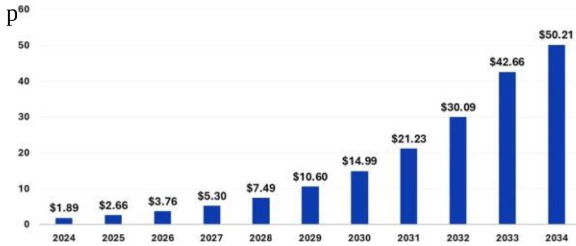

Fig 6 : AI in Telecommunication Market Size to hit USD

9.3. Potential Impact on Global Connectivity

When it comes to fully leveraging machine learning and other AI technologies in 5G management, we are just scratching the surface. What has become clear, however, is that adopting AI-driven solutions not only improves customer satisfaction but also benefits the bottom line, with TCO reduced by as much as 47%. At its core, the synergy of AI and 5G expands the power to connect, increase efficiencies, and create real value for all. As the world gets smarter, the amount of data that needs moving is a fast-growing tall order. By 2023, IP networks will deliver 189 exabytes of data per month, and 5G networks will support more than 10% of the global mobile connections, or about 1 billion employees roaming the front lines of finance, healthcare, retail, manufacturing, and other segments. Powering this increasing demand for data from next-generation services requires investments in designed elasticity to meet the needs of heavy-traffic market segments anywhere in the world, and the current global crisis is undoubtedly accelerating this transformation. AI-driven telecom system optimization and 5G network management.

10. Conclusion

The ever-growing amount of data traffic from ever more varied services necessitates high-capacity networking, which is enabled by next-generation telecommunication networks known as 5G, unfolding earlier than expected despite the uncertainty brought by the global pandemic. The field trials and outcomes from standards confirm and sustain the excitement around 5G and advanced 5G ecosystems. Both the standalone 5G for green fields and/or the non-standalone 5G networks for brownfields with the 4G evolution are currently possible; and operators are opting for one or the other based on the economics, spectrum, and level of service convergence. Therefore, good criteria for optimized 5G coverage models and energy-efficient designs are required to meet the explosive traffic growth expectations.

Although TM SmartBuildAI is targeted at deploying and optimizing 5G optical-core cities and extended 5GHaul in terms of fiber access, last-mile fronthaul, and mid-haul, TM SmartBuildAI is a general trailblazer that shows how AI can be instrumental in designing and deploying virtualized and service-oriented 5G. Furthermore, the architectural modeling of cost-effective multi-hop front hauls and optical-centralizing cores drives architectural design decisions. The TM SmartBuildAI software with input as geospatial, geodemographic, regulatory, spectral, technological, and environmental parameters; and a desired level of performance, including KPIs such as minimal energy requirement models, minimal deployment costs, green field optimization, digital infrastructure, or energy performance standards-compliant 5G networks. Inputs will be open from commercially available solutions with real-time spatial data, coverage modeling, traffic forecast protocols, and point-to-multipoint models, as well as from industry-standard system simulators. The output of simulation and optimization tools will be utilized during RAN planning, NFV implementations, regulatory verifications, geographic information system check software, field tests; and adaptive awareness models. The TM SmartBuildAI is seen as an enabler for predicting the market size, profitability, and global reach of the semiconductor business from fronthaul to the edge cloud, from the physical to optical-networking system orchestration, and network slicing management planes. Thus, minimizing the time-to-market of the chip-to-the-cloud and silicon-to-software is essential to help industry leaders, municipality developers, and cloud-infrastructure stakeholders book their urban customer experience milestone and subsequent 5G success.

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