

# Empowering the Future 5G Networks: An AI based Approach

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## ABSTRACT

The next telecommunications standard, 5G, envisions that the future networks will support advanced use cases, such as Internet of things while supporting voluminous simultaneous connections with high bandwidth as well as low latency. Further, these 5G deployments will not be static in nature, with new use cases and service requirements evolving in future. Such requirements pose many deployment and operational challenges to MNOs. These use cases would not only require the networks to be aware of connectivity related parameters, but also adapt intelligently based on parameters beyond the network. This requires the 5G networks to be capable of addressing conditions which are not foreseen at the time of designing them. Such capability requirements can be adequately addressed by advances in the field of AI and machine learning. The objective of this paper is to explore ways to leverage AI and machine learning for enhancing the 5G network deployments and operations. This paper attempts to decipher future demands from the 5G networks analyzing specific requirements in the areas of network planning, network operations and network optimization. This paper also discusses the strategic perspective for MNOs to benefit from applications of AI in 5G networks.

**Keywords:** 5G, AI, Machine Learning, 5G Challenges, Operations, Network Automation

## 1. INTRODUCTION

5G opens up several opportunities for the MNOs. However, with increasing competition and reducing margins, there is a dire need to ensure profitability while augmenting user experience. In this context, we look into the applications of AI and Machine learning for managing 5G networks. We have looked into three key phases of managing networks – Network planning, Network operations and Network optimization.

In network planning phase, AI can be utilized for better understanding of how the network will be used in dynamic conditions, thus leading to superior investment decisions. In the network operations & optimization phase, AI enables the 5G network to behave as an intelligent entity, while learning and evolving with time, leading to significant operational savings. Thus, AI technologies help MNOs to achieve both CAPEX and OPEX savings. We also explore how these AI applications can be leveraged in strategic decision making by MNOs. In the following sections, we will discuss how traditional ways of network management can be enhanced with help of AI.

## 2. ARTIFICIAL INTELLIGENCE

Artificial intelligence refers to the field of study related to making machines capable of human like intelligence. AI is not a new concept and has existed for decades. However, it's only recently that the vast potential of AI technologies seem to be realizable. This change has been possible due to significant growth of data with reducing cost for sensors, devices and storage. In general AI technologies can be applied to communication networks in two ways. First is a basic application where the control entity evaluates multiple pre-set solutions to respond to a given set of environment variables. Second and more advanced level of AI entails making the control entity intelligent to be able to learn from its experiences. Thus the system will have the capability to interact with its environment. The interaction would include sensing the changes, mining the data, predicting the outcomes and reason based on its past experiences. Thus the system is able to handle unknown scenarios on its own (Aman Naimat, 2016).

For this paper we focus on the advanced level of AI technologies used for making systems adaptable and learn with experience. This is referred to as machine learning

aspect of AI. Machine learning can be further categorized into supervised, unsupervised and reinforcement learning algorithms. Supervised learning involves learning from a set of input-output pairs, and may not be applicable for problems where desired output is unknown. Unsupervised learning is used when user does not know how to classify the inputs, and the system is expected to classify the data based on its statistical nature. Reinforcement learning includes the process of learning the behavioral model by sensing in a new environment, and taking decision which follows the process of feedback (reward or punishment) from the reward definition based on the outcome behavior. Thus the model tweaks itself based on the difference from the reward definition. We discuss further how these algorithms can be utilized in 5G networks to achieve strategic objectives such as cost optimization and enhanced user experience.

### 3. 5G NETWORKS

5G is a set of evolved network technologies aiming at providing ubiquitous connectivity to vast range of devices and applications (Ericsson, 2017). 5G networks do not rely on any one specific radio-access technology and entail support from a portfolio of access and connectivity solutions to address the mobile communication requirements beyond 2020.

5G will address huge traffic and bandwidth requirements while supporting wide range of connected devices and enabling real time, highly reliable communication for mission critical requirements. For supporting these requirements, the implementation and deployment of network infrastructure would undergo significant changes. This would have to be based on software-defined networking (SDN) and network functions virtualization (NFV). As per this trend network operations will become

more cloud enabled, and we see an obvious opportunity for leveraging AI to achieve cost optimization with enhanced customer experience in 5G networks.

## 4. ADDRESSING 5G NETWORK CHALLENGES WITH AI

According to ITU 5G standards, 5G cellular networks are key enablers to massive machine type communications, low latency services and high bandwidth consuming services. Data rates of tens of megabits per second for tens of thousands of users and several hundreds of thousands of simultaneous connections for wireless sensors are anticipated to be fulfilled by 5G. However, 5G just enables enhanced network function in pre-defined conditions. The requirements of enabling advanced configuration, dynamic networks and providing new service creates challenges for managing 5G networks. We elaborate how these challenges can be addressed through an AI framework, applying it to the 5G Cellular networks with an integrated architecture. We also showcase the use of this framework in addressing the challenges faced during network planning, operations and optimization phases.

### 4.1 AI based Framework

The below figure elucidates the framework for 5G network empowered with AI (J. Pérez-Romero, 2015) for network capacity planning, operations and optimization. The framework is based on input data from various sources, which is innovatively processed, to provide decisive actions to be performed on the network and to provide insights for assisting MNOs decisions through decision support systems.

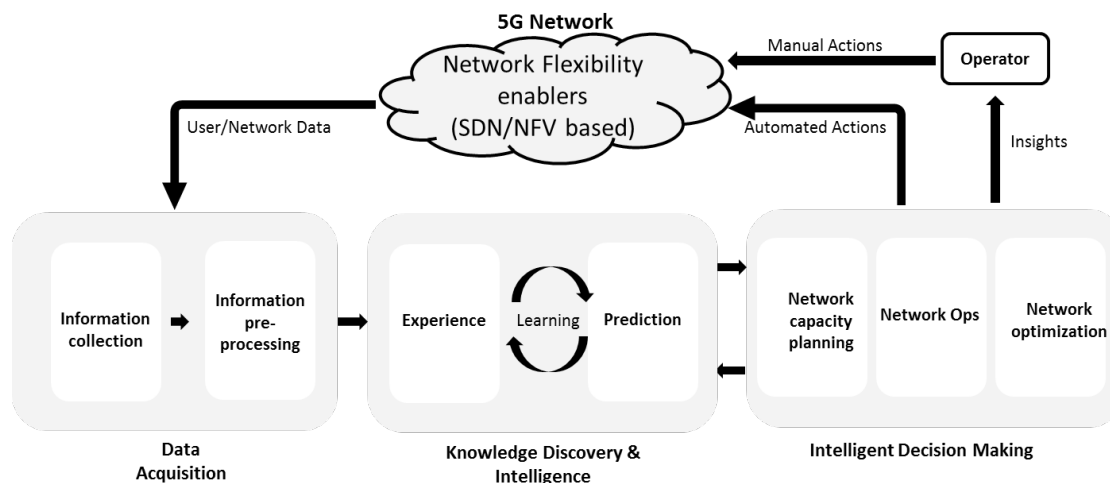


Fig. 1: AI based Framework for 5G Networks

#### 4.1.1 Data Acquisition and Pre-processing

5G network operations and planning faces challenges in analyzing and correlating complex and disparate sets of data, which resides in multiple systems such as CRM, NMS, BSS, inventories, etc. The data could be network data, user data, content data and external data.

During data pre-processing, the information from multiple systems is prepared for mining, through below tasks:

- Data cleaning – Includes removing in-consistent and noisy data.
- Data integration – Includes combining data from multiple sources.
- Data selection – Includes selecting relevant data specific to the problem.
- Data transformation – Includes changing / consolidating the data for further mining (e.g., summarizing, aggregating etc.).

#### 4.2 Knowledge Discovery & Intelligence

The Knowledge discovery stage uses machine learning tools, to build models which will drive network planning and operations decisions. As elaborated earlier the Machine learning techniques are usually subdivided into supervised, unsupervised and reinforcement learning. These can be used to identify algorithms & models based on input information.

Classification is the process of identifying model to describe and differentiate data sets. The identified model, called classifier is in turn used to determine the class. Further, Prediction identifies appropriate models to forecast the parameter values (e.g. the traffic requirements in a particular region can be anticipated with help of past trends and any changes in associated indicators). This is essential during network planning and is elaborated in future sections.

#### 4.3 Intelligent Decision Making

During this stage, the extracted knowledge, for e.g. prediction of traffic, will be used to recommend or decide actions for the network. These actions can be leveraged during network planning and operations processes

#### 4.4 Network Flexibility Enablers

SDN and NFV technologies, which enable dynamic 5G networks play an essential role in this AI based framework.

According to the Open Networking Foundation (ONF), software defined networking (SDN) is a network architecture that decouples the control and data planes, and provides a centralized view of the distributed network for more efficient orchestration and automation of network services, through a centralized application called SDN controller. This will enable the network control to become directly programmable and abstract the underlying infrastructure, for applications and network services. While NFV is a concept, which focuses on optimizing network services themselves, wherein the network functions such as DNS, Caching, etc are decoupled from proprietary hardware appliances, so they can run in software to accelerate service innovation and provisioning, particularly within service provider environments. These network programmable capabilities of SDN/NFV, key for achieving the real time needs of 5G, lay the foundation for deploying AI and Machine learning technologies. Detailed discussion on SDN/NFV is beyond the scope of this paper.

#### 4.5 AI Enabled 5G Cellular Networks

Figure 2 illustrates a viable 5G cellular network architecture, integrated with AI framework. The AI controllers sit on the top of the network entities, which act as applications. During the data acquisition stage, these AI controllers communicate with CN, RAN or SDN controllers, through open Interfaces.

AI center obtains the cellular network data through various heterogeneous sources such as SDN controllers etc, after which the AI center will utilize its inbuilt functionality (sense, mine, predict and reason), to provide recommendations or actions for performing on networks.

The AI center will read data from disparate systems such as:

- SLA - includes data on coverage, failure duration, redundancy, etc.
- UE - includes information specific to UE - any battery limitations or the category of receiver etc.

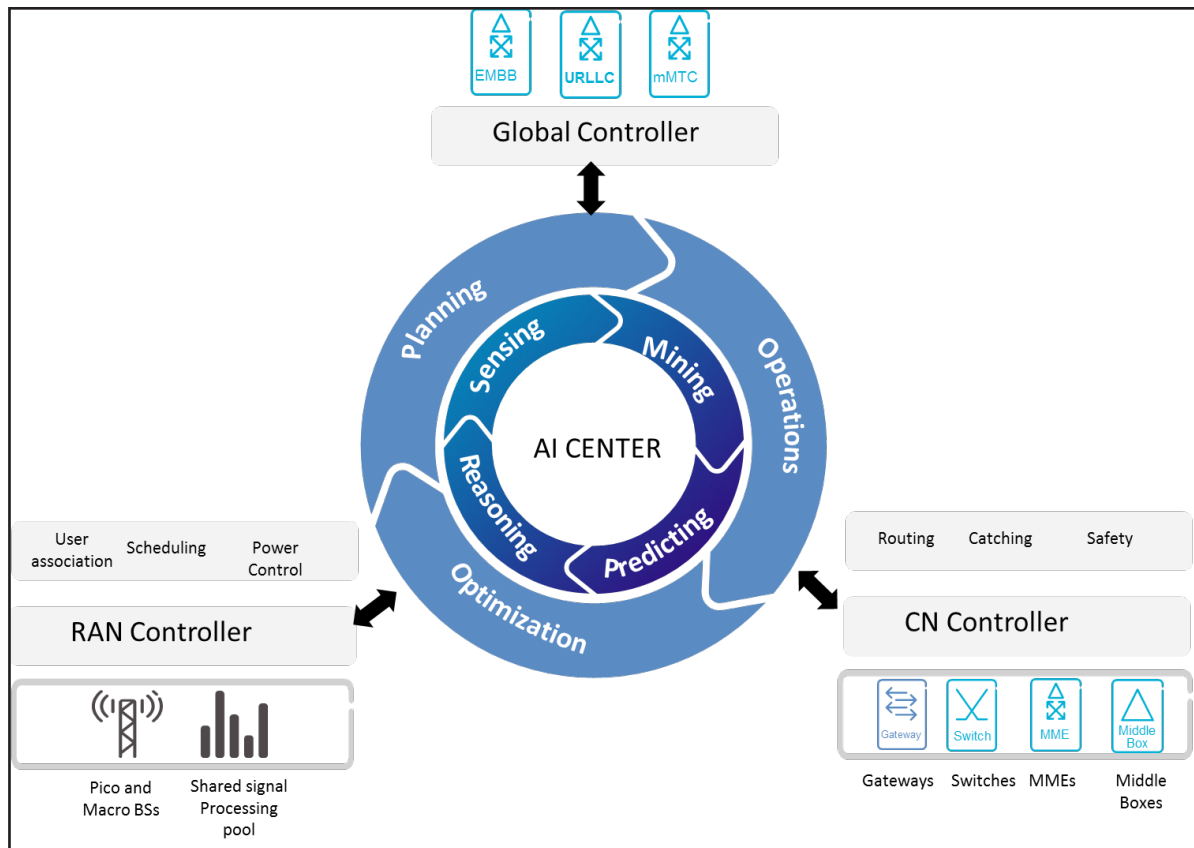


Fig. 2: 5G Architecture Enabled with AI

- Network - includes information such as #subscribers, spectrum, QoS, Network function KPIs, maintenance etc.
- Infrastructure - includes information such as CPU, memory, network standard, storage etc.

AI center will further processes the acquired data and provide recommendations on several aspects to the SDN controllers. The information includes Traffic analysis report (e.g., suggestions for the service provisioning), UE-specific data (e.g., allocation of bandwidth, priority of serving etc.) and notifications for network configuration (e.g., access methods, network alerts, and parameters for adjustment). This can be elaborated further discussing through planning, operations and optimization processes.

#### 4.6 Network Planning

An accurate network planning is a challenging process as planning methodologies involve various parameters which are uncertain and vary in time and space. Traditionally, this has often led to overprovisioning and, consequently, excess CAPEX. The challenges are exponentially increased in 5G networks, which are fueled by the volume, variety and velocity of data (J. Pérez-Romero, 2015).

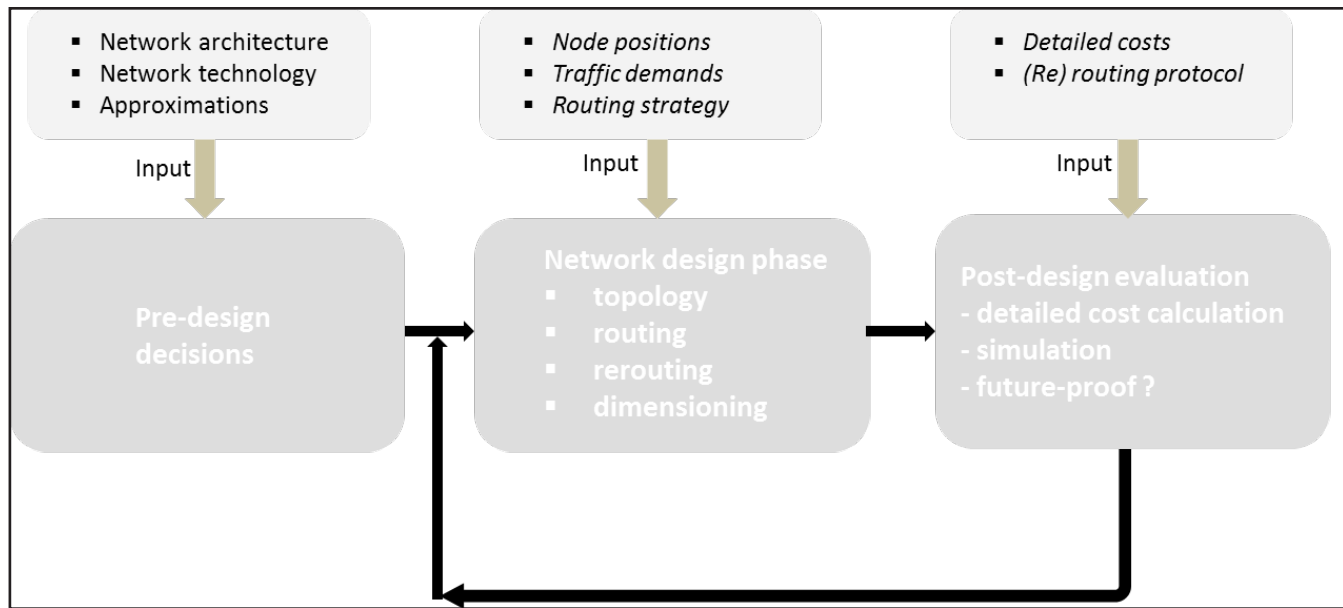
#### 4.6.1 Traditional Network Planning

Cellular network planning involves resolving a high number of complex issues, which include: Uncertainty of input parameters, Lack of accurate network details, and complexity of network.

The figure (Mario Pickavet, 2010) elaborates on a typical network planning process, in which the fixed inputs are provided as inputs to the iterative design process. Initially, pre-design parameters are decided such as choice of technology, network architecture, etc. Subsequently, based on these initial choices, the actual network is designed.

The network node and link capacities are dimensioned based on the routing strategy, demand of the traffic and the position of the link. Generally many approximations are applied during this phase.

After the actual network design, this is evaluated in detail from cost perspective, and is simulated, if necessary, to ensure if the actual traffic is aligned to the approximated traffic demands. Based on the evaluations, the pre design decisions are revisited.



**Fig. 3: Traditional Network Planning**

#### 4.6.2 Dynamic Network Planning

5G networks will be fueled by the emergence of big data analytics. Big data proposes an overwhelming amount of velocity, variety and volume, and is dynamic in nature.

Circumventing this problem, AI techniques like Simulated Annealing, Tabu Search and Genetic Algorithms can be used to solve complex network design problems.

In this process, AI center obtains the cellular network data through various sources such as SDN controllers etc, processes the acquired information and then feeds back the learning, leading to a dynamic architecture.

As highlighted earlier in this paper, the AI center includes modular capabilities to sense, mine, predict and reason the data. These AI modules are used in forecasting the traffic patterns that can be used as input for network planning with greater accuracy. For instance, the data obtained by tracking UEs location is leveraged by AI prediction module for forecasting mobility trend. Reasoning module proactively notifies UEs to update location record, to prepare handover resources and save signaling cost of mobility management.

Additionally, models can also be derived by decomposing the expected traffic demand from time, space and QoS perspectives. From the time and space perspectives, the fluctuations on the required capacity could be due to predictable conditions such as weekend and working days or unpredictable conditions such as accidents, etc. From the QoS perspective, the traffic decomposition

could utilize the dimensioning from space and time perspectives, and inference can be drawn by association with user groups. Traffic characterizations can also lead in identifying the mobility patterns, to extract data about daily movements.

Further, Classification techniques can be applied up to the cell level based on the traffic category and by using the prediction techniques, capacity can be dimensioned with greater accuracy. Few situations could lead to providing inputs to decision support systems in adopting spectrum trading strategy by MNOs.

#### 4.7 Network Operations

The critical tasks of network operations encompass configuration management, network monitoring and service provisioning.

#### 4.8 Configuration Management

Given the complexity of 5G networks, which are expected to cater to highly scalable and diverse devices, the configuration management and maintenance is cumbersome. The configurable parameters have evolved with the telecom technology. While there are 500 configurable parameters in a typical 2G node, 1000 are required in 3G nodes and the number rises to 1500 for a 4G node. Considering this trend, a typical 5G node could have 2000 configuration parameters (Rongpeng Li, 2017). Hence it becomes imperative to address configuration management with a highly automated approach.

The self-organizing features play a critical role in enhancing the intelligence in 5G era. The self-organizing features include self-configuration, self-optimization and self-healing. Self-configuration refers to the automatic configuration of the initial parameters that encompasses neighboring cells list, IP address and the radio access parameters.

For the automatic configuration of series of parameters for rendering best services, AI techniques like Transfer Learning (TL), RL and Dynamic Programming (DP) may be used in 5G. RL is a model free learning technique that yields superior results, which iterates through to reach optimal strategy. This is also suitable in the dynamically changing radio conditions (Rongpeng Li, 2017).

Self-healing encompasses automatic fault detection, classification of the faults and initiation of corresponding actions for recovery. AI sensing techniques such as Logistic Regression (LR), etc., can be leveraged to spot the irregularities and anomalies in the network, to further restore the system.

#### 4.9 Network Monitoring

Network monitoring could be challenging in 5G due to the dynamic nature of the cellular environment. Currently MNOs monitor the networks through alarms, which depend on static threshold setting at the cell level. As the network is dynamic, many alarms may be missed with traditional monitoring approach.

Traditional process of root cause analysis with trouble shooting guidelines also have clear limitations as they are associated with longer investigation times and increase the cost operations. Such processes can significantly impact customer satisfaction index.

With AI powered diagnostic analytics, MNOs can quickly and accurately detect network problems and resolve them, even before they occur. Algorithms like Logistic Regression (LR), Support Vector Machine (SVM), and Hidden Markov Model (HMM) could be used for network anomaly detection or events by multiple-entry data from heterogeneous sources.

#### 4.10 Service Provisioning

One of the remarkable evolutions in 5G is the feature of dynamic provisioning. The emergence of SDN & NFV has enabled a concept called Network Slicing which facilitates dynamic provisioning. Network slicing helps in creating customized network pipes for various services, which traditionally MNOs achieved by building

dedicated networks. It also ensures certain level of quality and security to each service (Ericsson, 2017).

The future services will require dynamic and automated network slicing via self-organizing property. It involves looking at various environment variables, learning uncertainties, planning appropriate actions and configuring the networks properly. AI could be utilized to learn the variation, classify the issues, forecast the future challenges and establish automated Network slicing.

We can automate service provision (latency, error rates and bandwidth) via AI techniques such as Gradient Boosting Decision Tree (GBDT) of supervised learning, and Spectral Clustering, one-class SVM of unsupervised learning.

#### 4.11 Network Optimization

Currently, network optimization involves manual processing & analysis and is highly supported by engineering knowledge. With the advent of dynamic 5G networks, and increasing complexity of network technologies, there is compelling need for the more automated and scalable solutions.

Optimization can be provided either via open loop systems or via closed loop systems. In open loop systems, the recommendations are provided to the network engineers, who control the network configuration. In closed loop systems, the NP&O system itself optimizes the network in near real time.

The closed loop optimization could be achieved through self-optimization which includes continuous optimization of parameters such as coverage, capacity and service quality by tuning different network settings. AI algorithms (unsupervised) like Kalman and Particle filtering can be utilized for dynamic optimization of networks.

### 5. AI ENABLING STRATEGIC OBJECTIVES

Depending on its strategic priorities, an MNO may want to focus on one or more of profitability (efficiency), brand differentiation (customer proximity) or market share (revenue). In our view, AI and Machine learning applications for network planning, operations and optimization help augment all of these strategic agendas. We have mapped various AI applications discussed in this paper to the business KPIs which are relevant for MNOs. This should facilitate decision making process to choose the right set of AI applications aligned with their business strategy.

**Table 1: Mapping AI Applications to Corporate Strategic Objectives**

<i>AI Application</i>	<i>Details</i>	<i>Business KPI / Metric</i>	<i>Corporate Strategy</i>
Network monitoring – self healing networks	Enhanced customer experience	CEM Score	Brand leader
Dynamic Network planning	Avoid deploying excess capex, leading to less capital burden and lesser depreciation / amortization expenses	Profitability	Cost Leader
Network capacity planning based on user mobility	Anticipate/Forecast user requirements and provide the required network capability	CEM Score	Brand Leader
Service provisioning via network slicing	Provision services efficiently and automatically	Profitability	Cost Leader
New services enabled via AI	Additional revenue via new service which would not be possible without AI	Revenue	Market Share Leader

Based on above, AI should be the top agenda for MNOs who are planning to deploy 5G networks in near future. Market research indicates that top global operators have already made huge investments in AI with BT Group, Orange, NTT and Verizon leading the pack as top investors. AT&T has also launched its Domain 2.0 initiative to transform its network and infrastructure into a highly dynamic system by replacing many of its current network elements with software using NFV infrastructure and controlling these software based components using SDN protocols. The initiative is very much based on the advanced machine learning algorithms. This trend is picking up and Telecoms.com reports that around 62% of the IT teams will be using AI by 2018 (Jason Riccio, 2016).

## 6. CONCLUSION

To conclude we would like to re-iterate that future networks offer opportunities as well as pose challenges for MNOs because of complexity involved in operating a 5G network. AI offers powerful algorithms which can be leveraged to manage these networks efficiently. These algorithms not only enable operators to estimate and plan capacity accurately but also enables significant cost savings via dynamic operations and network optimization. Thus, AI helps MNOs achieve their strategic objectives and hence we see increasing investments in this area. This is precursor to a huge demand for AI and Machine learning based systems for network planning, operations

and optimization, which will further be fueled by global 5G deployments.

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