A REVIEW ON QUALITY OF MONITORING FOR CELLULAR NETWORKS

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Abstract - *The quality of monitoring for cellular networks has become increasingly important with the introduction of 5G and 4G technologies. These technologies offer advanced features and capabilities that require effective monitoring to ensure reliable and efficient network performance. The aim of this paper is to provide an overview of the challenges and solutions in monitoring the quality of cellular networks. The paper will explore the different approaches and technologies used for monitoring the quality of 5G and 4G networks, including real-time monitoring, network traffic analysis, and fault detection and correction. Additionally, the paper will discuss the impact of 5G and 4G on the quality of monitoring and the importance of monitoring for ensuring network reliability and performance. The paper will conclude by highlighting the future outlook for quality of monitoring in cellular networks and the challenges and opportunities for improvement*

***Key Words*: QoM, cellular networks, data management, LTE-4G, and 5G**

1.INTRODUCTION

The growth of technology has resulted in an increase in demand for high-speed internet access and improved communication services. As a result, 5G and 4G cellular networks have been deployed to satisfy the expanding requirements of consumers. These networks provide quicker data transfer speeds, improved network capacity, and lower latency, making them suitable for mobile gaming, video streaming, and cloud computing.

However, the success of 5G and 4G networks is dependent on their capacity to continually deliver high-quality services. This needs good network performance monitoring to detect and handle any difficulties that may develop. Monitoring the quality of cellular networks entails evaluating key performance indicators such as network speed, coverage, and availability and ensuring that the network fulfills the intended criteria. Mobile devices are already commonplace in today's linked society, acting as essential tools for entertainment, business, and communication. For people, companies, and entire economies, cellular networks' flawless operation is not only convenient, but also essential. This emphasises how important monitoring is to maintaining the stability and dependability of these networks. A layer of complexity is added by the deployment of various technologies inside cellular networks, such as a combination of macrocells, small cells, and cutting-edge technologies like Massive MIMO (Multiple Input Multiple Output) and beamforming. Monitoring systems need to adjust to this diversity by offering thorough insights into every component's performance to ensure a coordinated and effective network functioning. Cellular network monitoring has taken on new dimensions with the introduction of the Internet of Things (IoT) and the continued deployment of 5G networks. Monitoring systems must be extremely accurate and responsive due to the vast number of linked devices, low latency requirements, and variety of use cases. As mobile networks take centre stage in the digital era, monitoring plays a critical role in guaranteeing the success of IoT rollouts and realising the game-changing promise of 5G.

As the telecoms industry continues to change, the importance of efficient cellular network monitoring has increased due to the introduction of revolutionary technologies like the Internet of Things (IoT) and the extensive rollout of 5G networks. Because of the wide variety of use cases and the proliferation of connected devices, monitoring systems need to be incredibly responsive in addition to being highly accurate. As Internet of Things (IoT) devices grow more and more essential to many industries, such as healthcare, smart cities, and industrial applications, reliable connectivity and low latency performance become critical. The key to making sure these IoT deployments run smoothly is cellular network monitoring, which lays the groundwork for the technologies' anticipated transformational impact.

Furthermore, the monitoring environment is confronted with new opportunities and problems as 5G networks continue to grow, bringing unprecedented speed and connectivity capabilities. The cellular infrastructure becomes more sophisticated when advanced technologies like beamforming and Massive MIMO are implemented. Systems for monitoring must adjust to this diversity and provide thorough insights into the operation of every network component. The capacity of monitoring systems to identify and resolve problems quickly is critical to the success of 5G and its potential to revolutionise a number of industries by preserving the stability and reliability of these high-performance networks. Cellular network monitoring essentially becomes a crucial facilitator in the digital age when mobile networks are the focal point, guaranteeing the fulfilment of the revolutionary potential of both IoT and 5G technologies.

In this article, we will look at the necessity of monitoring quality for cellular networks as well as the various methodologies and technologies used to monitor 5G and 4G networks. We will also explore the influence of 5G and 4G on monitoring quality and emphasize the future prospects for monitoring quality in cellular networks.

2. LITERATURE SURVEY

Evaluation of research works on networking quality monitoring is the goal of this section.

According to one study, immediately detecting and addressing any problems with the network requires real-time network monitoring. Network traffic monitoring is crucial for identifying network congestion and enhancing network performance, the report further noted. An other research study examined how to monitor the quality of cellular networks through the use of fault detection and rectification. Good problem detection and repair systems may reduce network outages and increase network dependability, according to the study's findings.Studies on the effects of 4G and 5G on monitoring quality have also been conducted. The deployment of 5G has increased the number of devices linked to the network, raising the need for monitoring. A different research covered the difficulties in keeping an eye on both 5G and 4G networks, emphasising the necessity for high-speed surveillance and the fusion of various monitoring systems.

Naser Hossein Motlagh and Shubham Kapoor[1]provide the Quality of Monitoring (QoM) concept as a workaround to reduce the amount of M-Plane data currently at the NEs. In order to create Key Performance Indicators (KPIs), the raw M-Plane data is first aggregated by QoM. Information loss limits for QoM classes specific to each KPI time series are established by the QoM using a data-driven algorithm to these KPIs. After the classes have been applied, the KPI data is compressed by the QoM using a lossy-compression method, which is a variant of the Piece-Wise Constant Approximation (PWCA) algorithm. Utilising M-Plane raw data from an operational LTE network, they calculate four KPIs, each with distinct statistical characteristics, to evaluate the effectiveness of the QoM solution. Also define three QoM classes: Exact, Optimised, and Sharp.The class Optimised has a higher compression rate than the class Exact, but the class Sharp has the highest compression rate overall. This article assumes, for example, that NEs in a network generate 280 MB of raw data containing information that must be sent to the network operations centre. KPIs are used to characterise the information contents of the data, and a QoM solution is used to send the data over the network. As a result, the QoM technique achieves an estimated 95% compression gain from the raw data in transmission.

QoM delivers an amazing estimated compression increase of 95% in a real-world scenario where NEs in a network generate 280 MB of raw data that needs to be transmitted to the network operations centre. This demonstrates how well the QoM solution works to ensure efficient network management, simplify data transmission, and lighten the load on network resources. In addition to offering a workable approach for managing substantial amounts of M-Plane data, Motlagh and Kapoor's work lays the groundwork for more effective and data-conscious network monitoring techniques in the rapidly changing telecoms industry.

Faraz Ahmed, Jeffrey Erman et al[2] suggest using M2M devices as field-based sensors to improve the evaluation of customer-perceived service quality. This gives cellular network operators a previously unheard-of chance to monitor end-user experiences more accurately and comprehensively. Their method involves locating a group of M2M devices that remain in one place and interact nonstop for an extended amount of time via the cellular network. During cell site failures, they employ these M2M devices to measure the customer-perceived service level. They approach is put into practice as a system known as M2MScan, which assess using both artificial and actual failures from a sizable operating cellular network. Suggest using M2M devices as field-based sensors to improve the evaluation of customer-perceived service quality. This gives cellular network operators a previously unheard-of chance to monitor end-user experiences more accurately and comprehensively. In order to analyse and estimate the fine-grained service effect on customers during cell site failures, it designs and evaluates an M2MSourcing-based fine-grained service impact analysis system called M2MScan. M2MScan watches the communication activity of M2M devices. In order to proceed, First locate a sizable number of M2M devices that meet specific requirements, such stationarity, communication frequency (always awake), and spatial dispersion. Then, Evaluate the fine-grained service effect during cellular network failures by measuring the user-perceived service quality in various geographic regions using the communication pattern of an identified collection of stationary M2M devices. The major technique used in this research is the deployment of a collection of M2M devices that stay in one place and communicate with each other constantly over an extended length of time over the cellular network. Because of this special configuration, the researchers may measure and evaluate the customer-perceived service level during actual operational issues by using these M2M devices as probes during cell site failures. The product of their labours is a system called M2MScan, which functions as a real-world application of their methodology.

M2MScan uses a mix of real and fake failures from a large operational cellular network, enabling a thorough assessment of its performance. The technology is intended to assess and calculate the impact of specific cell site failures on customers' fine-grained service. A fine-grained service impact analysis system based on M2MSourcing is introduced by M2MScan in order to accomplish this. First, the system finds a large number of M2M devices that satisfy certain requirements, including spatial dispersion, continuous communication frequency (staying awake constantly), and stationarity. Following the establishment of this M2M device network, M2MScan keeps an eye on these devices' communication activity. The distinct benefit resides in the capacity to measure user-perceived service quality in many geographic locations, hence accurately assessing the fine-grained service effect during cellular network outages. This is accomplished by carefully examining the communication patterns of the selected group of fixed M2M devices.

M2MScan gives cellular network operators a potent tool to identify and resolve problems during cell site failures as well as to obtain insightful information about user experiences across various locations by employing M2M devices as strategic probes in this way. With the help of an all-encompassing and data-driven strategy, operators will eventually be able to make well-informed decisions to improve and optimise network performance by gaining a more nuanced understanding of how customers perceive the quality of their services. Ahmed, Erman, and colleagues' research thus represents a major breakthrough in the field of cellular network service quality assessment.

Guilherme A. Barreto et.al[3] and his associates introduce a brand-new unsupervised condition monitoring technique for cellular networks that improves anomaly detection accuracy and efficiency by applying competitive neural algorithms. Their method involves using state vectors to train the system, which mimic the normal functioning of a simulated CDMA2000 network. Following the training phase, the distribution of the training state vectors' quantization errors and their constituent parts are used to build local and global normality profiles (NPs).

The global NP is a thorough evaluation of the general condition of the cellular system. A comprehensive grasp of the system's behaviour under typical operating settings is made possible by this wide overview. On the other hand, when abnormal behaviour is recognised, local NPs are applied strategically and component-wise, making it possible to identify anomalous state variables. This refined method makes it easier to respond specifically to anomalies by offering a more detailed understanding of particular cellular network components.

The researchers use percentile-based confidence intervals computed over the global and local NPs to perform anomaly identification tests. For this objective, the efficacy of four competing algorithms is compared: winner-take-all (WTA), frequency-sensitive competitive learning (FSCL), self-organizing map (SOM), and neural-gas algorithm (NGA). The comparison's results show that using global and local NPs together is more dependable and efficient than the current single-threshold methods.

This study emphasises how important it is to use competitive neural algorithms in cellular network condition monitoring. The technique not only improves anomaly detection capabilities but also offers a more sophisticated insight into network behaviour, allowing operators to react to anomalous circumstances with greater efficiency. According to the results, a thorough strategy that takes into account both local and global viewpoints is necessary for reliable and effective anomaly identification in the dynamic and intricate world of cellular networks. The knowledge gained from this study could aid in the creation of increasingly complex and adaptable monitoring systems as cellular networks continue to change.

Pedro Casas, Michael Seufert et al[4] provide a thorough analysis that uses a multifaceted strategy to handle the important problem of Quality of Experience (QoE) provisioning in cellphones. Their study examines quality of experience (QoE) from two main angles: passive end-device measurements and crowdsourced QoE feedback from functional cellular networks, along with observations from subjective lab testing.

The goal of the study is to comprehend how access bandwidth and latency affect the quality of experience (QoE) of five well-known web services and mobile applications: Google Maps, WhatsApp, Facebook, YouTube, and Chrome web browsing. Interestingly, the study explores the effects of both dynamically and continuously changing network access conditions, focusing on the common situation of changeable downlink bandwidth in cellular networks. A notable contribution of this work is the illustration of how effectively, using mappings that faithfully represent users' supplied QoE, laboratory results correspond with actual world settings. The research offers significant understanding of the complex connection between network circumstances and users' perceptions of quality of experience for a variety of applications.

The results of this study not only improve our knowledge of the QoE needs for popular mobile apps, but also offer useful suggestions for optimising the underlying provisioning network. This study is noteworthy for being the first to provide a comprehensive analysis of quality of experience (QoE) on mobile devices by effectively fusing insights from controlled lab experiments and network data with user input on QoE in operational networks. With implications for both network operators looking to improve service quality and developers trying to optimise the user experience across a variety of mobile applications in the constantly changing world of cellular networks, this all-encompassing approach positions the research as a foundational contribution to the field.

Li Erran Li et al. [5] this study propose the implementation of Software-Defined Networking (SDN) as a revolutionary method to simplify the design and maintenance of cellular data networks, as well as to enable the introduction of new services. They suggest that Software Defined Networking (SDN) is a viable path to streamline the complexities involved in network administration and improve the flexibility of cellular networks. However, the authors agree that future SDN systems, especially in the context of cellular data networks, must address a few scaling issues. The challenges related to scaling that have been highlighted include managing the frequent user mobility, putting in place precise measurement and control systems, guaranteeing real-time adaptation to changing network circumstances, and offering stable support for a large number of subscribers. In order to get around these problems, the authors suggest adding extensions to SDN systems that would enable controller applications to express high-level policies independent of addresses and locations, depending on subscriber properties. This change makes network administration more flexible and abstract.

Using local agents on the switches to implement real-time, fine-grained control is another suggested improvement. With this method, network characteristics may be precisely and dynamically adjusted, allowing the cellular data network to adapt in real-time to the shifting demands and conditions. The authors also support the addition of features to packets, such as header compression and deep packet inspection, in order to further maximise network performance and efficiency. Most importantly, the authors suggest using SDN capabilities to remotely control base-station resources, which are an essential component of the infrastructure of cellular networks. This remote management feature enhances the network's overall adaptability and flexibility, facilitating the effective distribution and use of its resources.

Lastly, the authors contend that SDN may overcome its present scaling issues and realise its full potential in the field of cellular data networks by integrating these suggested expansions into the controller platforms, switches, and base stations. According to this forward-looking viewpoint, the combination of SDN and cellular networks might bring in a new era of simpler network management, enhanced user experiences, and innovative services in the ever-changing telecoms industry.

Eirini Liotou al[6] the purpose of this article is to provide light on the field of network-level quality of experience (QoE) management by highlighting open challenges and defining necessary actions for promoting QoE support and awareness in mobile cellular networks. In order to accomplish this goal, the paper offers a thorough examination of the architecture, elements, and interactions that are essential to a suggested conceptual framework for end-to-end QoE provisioning. As a fundamental structure, the framework is intended to serve as a link between the conventional network-centric methods and the emerging user-centric paradigms. Through emphasising the essential components of this theoretical structure, the paper advances a more comprehensive comprehension of the complex interactions between network architecture and user experience.

The paper explores the implementation details of the suggested framework in addition to explaining its theoretical foundations. A review of the primary implementation obstacles is given, covering problems that could come up when a user-centric QoE management system is deployed and integrated into current or future mobile cellular networks. This practical analysis clears the path for more efficient and successful implementation techniques by helping to foresee possible roadblocks.

Seiamak Vahid et al[7] on this paper tell with the impending deployment of 5G networks, a number of new opportunities and problems arise. Three major factors to take into account are mobility support, data throughput, and the crucial Quality of Experience (QoE) measure. The "1000-fold capacity increase," which is often mentioned and emphasises the scope of the improvements anticipated in this next stage of wireless communication technology, captures one of the recurrent themes in these difficulties. The upcoming 10 years are expected to see a remarkable increase in data traffic, primarily due to rising customer demand for services and applications that require large amounts of data. This spike in demand paves the way for 5G technology's revolutionary potential, which is expected to meet if not surpass the growing need for data. A key component of this expectation is the belief that 5G may accomplish this amazing accomplishment while also lowering installation costs and providing end users with quick and affordable broadband access.

To tackle the unparalleled surge in data traffic, a diverse strategy is required. First of all, it is acknowledged that the distribution of extra spectrum is an essential requirement. Increased data-carrying capacity made possible by a larger spectrum enables the network to efficiently handle the spike in data demand. Second, it becomes critical to increase spectral efficiency, which is expressed in bits per Hertz per cell. Increases in spectral efficiency guarantee that every unit of available spectrum is used more efficiently, which improves network performance and data throughput. In addition, the 5G roadmap endorses the use of more numerous, smaller cells per square kilometre, recognising the importance of increased cell densification. Coverage, capacity, and overall network performance are all intended to be optimised by this approach. Smaller cells proliferate because they make better use of the spectrum that is available, reduce interference, and improve the network's capacity to serve the varied demands of an increasingly interconnected world.

Raed Abduljabbar Aljiznawi et.al[8] design and deployment of 5G networks are supported by distinct functional specifications as well as the expected traffic patterns linked to the widespread use of large-scale Machine-to-Machine (M2M) services and high-definition (HD) video streaming, both of which are expected to be in high demand. Based on these considerations, suggested Quality of Service (QoS) standards are made, which represent the need to support a wide range of demanding use cases in the ever changing communication technology landscape.

Network Function Virtualization (NFV), which includes the virtualization of essential network services including cloud radio access and cloud core networks, is a fundamental idea in the construction of 5G networks. In this regard, the study recommends that the cloud QoS control function (CQCF) and cloud QoS management function (CQMF) be incorporated as essential parts of the cloud architecture of the 5G network. These function blocks are essential for keeping an eye on and managing quality of service (QoS), which makes sure the network can adjust dynamically to changing demands and provide the best possible performance for various services. Additionally, the study highlights the ongoing demand for quick and dependable communication services, which is pushing the necessity for the advancement of increasingly complex monitoring technologies. The implementation of CQMF and CQCF is a calculated step towards improving QoS control in 5G networks, in line with the constantly increasing need for dependable connectivity and economical resource use.

Concurrently, an additional research endeavour explores improving monitoring methods for 4G and 5G networks. This entails developing increasingly sophisticated monitoring instruments and using machine learning techniques to improve monitoring capabilities. Large-scale network data analysis can be automated with machine learning, allowing for proactive anomaly detection, resource allocation optimisation, and problem prediction. The search for increasingly sophisticated monitoring tools is a sign of a dedication to staying ahead of the rapidly changing technological scene and making sure that monitoring techniques develop in step with the complexity of 5G networks.

Ayman A. El-Saleh, Abdulraqeb Alhammadi et.al[9 analysing the performance of Mobile Broadband (MBB) in Cyberjaya City, Malaysia, offers important insights on the operational effectiveness of the main MNOs in the area. Drive tests were used in the study to collect measurement data from well-known MNOs, including Digi, U Mobile, Maxis, Celcom, and Unifi. These MNOs support both 4G and 3G technologies. A thorough assessment of the mobile network environment is provided by the emphasis on multiple performance metrics, such as signal quality, throughput, ping, and handover, in both indoor and outdoor environments. Notable results for every MNO were revealed by the study during the outside drive test measurements. For real-time applications and user experience, responsive network performance is indicated by minimum average ping times of 36.5 ms and 0.14. Furthermore, remarkable downlink and uplink data rates of 14.3 and 7.1 Mbps, respectively, were shown for the greatest average throughput. These findings highlight the MNOs' capacity to meet users' increased demand for data-intensive services by offering high-speed access.

The study does acknowledge the value of indoor testing, though, as it takes into account the variety of situations that consumers can face. Considering the possible difficulties related to indoor signal propagation, the average data rate of 2 Mbps recorded during in-building tests suggests a reasonable degree of service. This evaluation emphasises the MNOs' capacity to sustain consistent and respectable indoor performance, which helps to provide a uniform user experience in a variety of usage scenarios. The analysis becomes more complex when performance factors like handover evaluations are included in a larger context. For uninterrupted connectivity, efficient handovers are essential, particularly in dynamic mobile contexts where users are constantly on the go. The analysis of handover performance in the study sheds important light on the MNOs' capacity to sustain connectivity when switching across various network cells. The drive test findings collectively demonstrate the major MNOs' ability to provide dependable, high-speed mobile connectivity and offer a positive picture of the MBB performance in Cyberjaya City, Malaysia. The study adds to a more complex understanding of the mobile network environment in the area by emphasising both indoor and outdoor settings and by including a variety of performance metrics. Studies of this kind are essential for assessing the efficacy of MBB services and pinpointing areas that could be improved to satisfy the rising expectations of users in a digitally connected society as mobile technologies continue to advance.

Pedro Casas et.al[10] analysis of user-centric performance under different network conditions is presented by looking at how access bandwidth and latency affect the Quality of Experience (QoE) for a variety of services and mobile applications, such as Facebook, YouTube, Google Maps, WhatsApp, and web browsing via Chrome. With a focus on variable downlink bandwidth—a typical situation in cellular networks—this study especially examines the effects of constantly and dynamically changing network access conditions outside of laboratory settings. The research has made a noteworthy contribution by showcasing the practical application of its laboratory results. The fact that the mappings generated from the lab trials closely resemble the quality of experience (QoE) that users encounter in real networks highlights the reliability and usefulness of the study's conclusions. This agreement between experimental findings and actual user experiences emphasises how crucial it is to take dynamic and changeable network circumstances into account when evaluating QoE for widely used applications.

The important topic of end-device passive measurements and analysis is also included in the study. Through an exploration of the end-user viewpoint and the integration of passive metrics, the study offers a more comprehensive comprehension of the complex correlation between network efficiency and user contentment. In addition, the research provides recommendations and bandwidth thresholds for attaining the best quality of experience (QoE) in a variety of applications, providing useful information for network administrators and application developers. The study demonstrates how easily lab results can be applied to real-world circumstances, which advances our understanding of the complex relationships that exist between user experience and network performance. This refined knowledge is especially helpful for guiding the development of Long-Term Evolution (LTE) technologies and upcoming 5G networks. The results not only clarify the particular difficulties caused by fluctuating downlink bandwidth, but they also provide useful recommendations for putting end-device measurements and QoE-based monitoring into practice.

3. COMPARATIVE ANALYSIS

Table -1: Comparative Analysis Table

COMPARATIVE ANALYSIS			
S.no	**Study of**	**Method**	**Features /Limitations**
1	Naser Hossein Motlagh, (2022)	Quality of Monitoring for Cellular Networks	QoM solution by considerable compression of the M-Plane data at the network edge
2	Faraz Ahmed, Jeffrey Erman	M2M devices to estimate the customer perceived service quality	M2MScan and evaluate M2MScan with both synthetic outages and real outages from a large-scale operational cellular network
3	Guilherme A. Barreto	CDMA2000 network, normality profiles (NPs)	Global and local NPs is more efficient and more robust than current singlethreshold methods
4	Pedro Casas, Michael Seufert, Florian Wamser	Quality of Experience (QoE)	Analysis of QoE in mobile devices, combining network measurements with users QoE feedback in lab tests and operational networks
5	Li Erran Li	Software defined networking (SDN)	Supporting many subscribers, frequent mobility, fine-grained measurement and control, and real-time adaptation
6	Eirini Liotou,[2013]	QoE	HeNB based on QoE-unaware criteria
7	Seiamak Vahid, Rahim Tafazolli and Marcin Filo	mobility support and QoE	The next generation of small-cell networks will require more spectrum that is only available at mmWave bands.
8	Raed Abduljabbar Aljiznawi	M2M, QoS, video services	QoS control will be maintained during the transition from 4G to 5G, the main effort of 5G developers should be focused on the virtualization of network functions, responsible for the management and control of QoS in the network
9	Ayman A. El-Saleh , Abdulraqeb Alhammadi	Mobile broadband (MBB) services	MBB suppliers should enhance their experience quality and performance networks in order to satisfy clients
10	P. Casas, M. Seufert, F. Wamser	Quality of experience (QoE)	Gives some first elements for such a comprehensive examination. There are several restrictions on the connection between field and lab results.

3. CONCLUSIONS

The quality of monitoring continues to be crucial to the dependability and efficiency of both 5G and 4G cellular networks in the ever-changing telecom environment. Network operators are forced to employ state-of-the-art monitoring tools in order to satisfy customers' ever-increasing needs as consumer expectations rise and technology develops. Since real-time monitoring gives operators instantaneous insights into network performance, it has become an indispensable tool for swiftly resolving faults and optimising resource allocation. Maintaining the high performance, speed, and coverage standards demanded by contemporary cellular networks requires a proactive strategy.

The sophistication of network traffic analysis has grown, enabling operators to explore the nuances of user behaviour and data flow. This fine-grained comprehension facilitates capacity planning, guaranteeing that the network can manage the rapidly increasing data traffic resulting from the widespread use of mobile devices and the increasing ubiquity of data-intensive apps. By quickly detecting and resolving problems, reducing downtime, and improving overall quality of service, fault detection and correction procedures also help to strengthen the resilience of networks.

The introduction of 5G has created both new monitoring opportunities and challenges. Even more accurate and responsive monitoring systems are required in order to achieve the ultra-low latency and huge device connection that 5G promises. In order for 5G networks to fulfil their revolutionary promise and support a wide range of use cases, from mission-critical IoT deployments to augmented reality applications, the quality of monitoring will be crucial.

Quality monitoring in cellular networks seems to have a bright future. Future developments in monitoring technology will undoubtedly occur as a result of the necessity to adjust to changing user expectations and network topologies. Artificial intelligence and machine learning could become more and more important, allowing automatic responses and predictive analytics to address possible network problems before they affect users. In order to guarantee that customers continue to enjoy smooth and superior services from their cellular networks, quality monitoring's proactive and adaptable nature will be essential as long as there is a need for high-speed internet connectivity and technologies continue to advance.

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