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A Systematic Literature Review on Quality of Service in 5G Cellular Networks: Challenges and Opportunities in the Indonesian Context

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abstract

The fifth-generation (5G) network promises ultra-fast connectivity, massive device density, and low latency, yet ensuring reliable Quality of Service (QoS) remains a major challenge. This study conducts a Systematic Literature Review (SLR) of 35 peer-reviewed articles published between 2020–2023, sourced from IEEE Xplore, Scopus, and Google Scholar. The review identifies key QoS mechanisms such as network slicing, resource allocation, and latency management, while challenges persist in scalability, interoperability, and security. Emerging trends highlight the growing role of Artificial Intelligence (AI), Machine Learning (ML), and Software-Defined Networking (SDN) for QoS optimization. In Indonesia, regulatory readiness, spectrum allocation, and uneven infrastructure present both challenges and opportunities. The study contributes by synthesizing recent findings, outlining research gaps, and offering practical insights for policymakers, operators, and researchers.

abstrak

Jaringan 5G menjanjikan konektivitas ultra-cepat, kapasitas perangkat masif, dan latensi rendah, namun penyediaan Quality of Service (QoS) yang andal masih menjadi tantangan utama. Penelitian ini melakukan Tinjauan Literatur Sistematis (SLR) terhadap 35 artikel peer-reviewed terbitan 2020–2023 dari IEEE Xplore, Scopus, dan Google Scholar. Hasil menunjukkan bahwa QoS dipengaruhi oleh network slicing, alokasi sumber daya, dan manajemen latensi, sementara tantangan tetap pada aspek skalabilitas, interoperabilitas, dan keamanan. Tren terbaru menekankan peran Artificial Intelligence (AI), Machine Learning (ML), dan Software-Defined Networking (SDN) dalam optimasi QoS. Dalam konteks Indonesia, kesiapan regulasi, alokasi spektrum, dan ketimpangan infrastruktur menghadirkan hambatan sekaligus peluang. Kajian ini menyintesis temuan terkini, mengidentifikasi gap penelitian, serta memberi implikasi praktis bagi pembuat kebijakan, operator, dan peneliti.

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1. Introduction

The rapid development of mobile communication technologies underscores the urgent need to study Quality of Service (QoS) in 5G networks. In Indonesia, the implementation of 5G is closely linked to national strategies for digital transformation, smart cities, and Industry 4.0. However, ensuring reliable QoS remains a significant challenge that impacts both users and service providers. QoS directly influences user satisfaction, supports critical applications such as autonomous vehicles and healthcare, and affects the competitiveness of telecommunications providers (Kamal *et al*., 2021). This study aims to systematically review the existing literature on QoS in 5G cellular networks, focusing on identifying challenges and opportunities within the Indonesian context. The research seeks to answer three primary questions: (1) What are the main parameters and mechanisms of QoS in 5G networks? (2) How do global studies analyze QoS in relation to new technologies such as network slicing and AI? (3) What challenges and opportunities are specific to Indonesia in implementing QoS for 5G?

5G represents the latest generation of cellular network technology, designed to deliver significantly higher internet speeds, reduced latency, and greater capacity compared to its predecessors, such as 4G. The evolution of 5G is generally categorized into three key service domains: Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC), and Massive Machine-Type Communications (mMTC) (Panwar *et al*., 2020). The eMBB domain focuses on improvements in download and upload speeds as well as network capacity, with 5G capable of achieving download speeds up to 10 Gbps—more than ten times the capacity of 4G. URLLC focuses on ultra-reliable and low-latency data transmission, where latency can be reduced to as low as 1 ms, nearly ten times lower than that of 4G, enabling applications requiring real-time responsiveness. The mMTC domain addresses large-scale connectivity needs, particularly for the Internet of Things (IoT), with 5G networks capable of supporting up to one million devices per square kilometer, ensuring efficient and scalable connectivity. In summary, Quality of Service (QoS) in 5G networks presents substantial enhancements over previous generations, providing faster, more responsive, and reliable connectivity for both users and applications. The topology of 5G networks is designed to provide fast, reliable, and secure connectivity. Generally, there are two common types of 5G network topologies: Standalone (SA) and Non-Standalone (NSA) (Saad *et al*., 2020). The SA topology allows 5G networks to operate independently, without relying on 4G or earlier technologies, offering greater flexibility and higher data transmission speeds. Conversely, the NSA topology uses existing 4G infrastructure to support 5G connectivity, enabling faster and more cost-effective deployment of 5G services without requiring extensive investments in new network infrastructure.

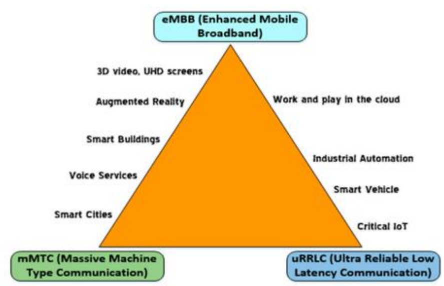

Figure 1. Technical 5G Scenario

The architecture of 5G networks introduces a service-based framework that marks a significant departure from previous generations. It is designed to support flexible deployment, scalability, and the integration of emerging technologies (Saad *et al*., 2020). The 5G core network (5GC) consists of several key functional components, each playing a crucial role in maintaining the overall performance of the network. The gNB (Next Generation Node B) serves as the base station, facilitating wireless communication between user equipment (UE) and the core network. It supports both standalone (SA) and non-standalone (NSA) modes, enabling diverse deployment strategies. The Access and Mobility Management Function (AMF) is responsible for handling user registration, mobility management, and access authentication, ensuring seamless connectivity as users move across different cells. The Session Management Function (SMF) manages the establishment, modification, and release of sessions, playing a central role in IP address allocation and coordinating traffic flows with the User Plane Function (UPF). The User Plane Function (UPF) handles the actual forwarding of user data packets, ensuring optimal Quality of Service (QoS) by managing routing, policy enforcement, and traffic management. The Network Slice Selection Function (NSSF) enables the implementation of network slicing, allowing users and services to be assigned to specific slices based on performance requirements. Lastly, the Policy Control Function (PCF) manages policy rules related to QoS, mobility, and charging, ensuring that service requirements align with available network resources. This modular and service-based structure of the 5G core network allows for the implementation of network slicing, cloud-native deployments, and the integration of advanced technologies such as Software-Defined Networking (SDN) and Network Function Virtualization (NFV). These features enable 5G networks to support a wide range of applications, from enhanced mobile broadband (eMBB) to ultra-reliable low-latency communications (URLLC) and massive machine-type communications (mMTC) (Rahman *et al.*, 2023; Li & Li, 2022). The overall architecture of 5G is designed to ensure fast and reliable connectivity across the system, particularly in densely populated environments. It consists of three main components: the Radio Access Network (RAN), which includes base stations and other radio equipment responsible for transmitting data to and from 5G devices; the Core Network (CN), which connects all devices and servers within the 5G system and is responsible for organizing, processing, and managing data; and the Service Management and Orchestration (SMO), which is responsible for managing all available services, including data, voice, and video services. With this architecture, 5G networks are equipped to deploy advanced applications such as autonomous vehicles, the Internet of Things (IoT), and virtual reality (VR), offering new possibilities for future technological advancements (Panwar *et al.*, 2020).

Figure 2. 5G Network Architectur

The regulations and standards governing 5G technology play a crucial role in ensuring its effective deployment both globally and in Indonesia. At the global level, the 3GPP (Third Generation Partnership Project) is a key organization responsible for developing telecommunications standards, including those for 5G, establishing frameworks for both non-standalone (NSA) and standalone (SA) 5G networks. The ITU (International Telecommunication Union), a specialized agency of the United Nations, regulates radio frequency spectrum usage and sets standards for telecommunications technologies, including minimum data rates and spectrum availability for 5G networks. The EU (European Union) has set a minimum 5G speed target of 100 Mbps and launched the European 5G Action Plan to accelerate 5G infrastructure deployment across its member states. Similarly, in the United States, the FCC (Federal Communications Commission) oversees cellular communications and has issued licenses for 5G frequency bands, actively supporting the nationwide development of 5G networks. In Indonesia, the development and deployment of 5G are regulated by the Ministry of Communication and Information Technology (Kominfo) and the Indonesian Telecommunication Regulatory Authority (BRTI). Kominfo has allocated specific frequency bands, such as 2.3 GHz, 2.6 GHz, and 3.5 GHz, for the initial rollout of 5G networks, with plans to utilize millimeter-wave (mmWave) bands above 24 GHz in the future to support high-capacity services. All 5G infrastructure and equipment in Indonesia must comply with technical standards set by Kominfo, aligning with global standards from the ITU and 3GPP. Indonesia's 5G deployment strategy prioritizes metropolitan and industrial areas with high demand for advanced connectivity, such as Jakarta and Surabaya, with plans for gradual expansion to other regions. Additionally, the government encourages collaboration among operators, technology providers, and academia to foster local 5G use cases, including applications for smart cities, the Internet of Things (IoT), and Industry 4.0, thus fostering innovation and contributing to the national digital transformation agenda.

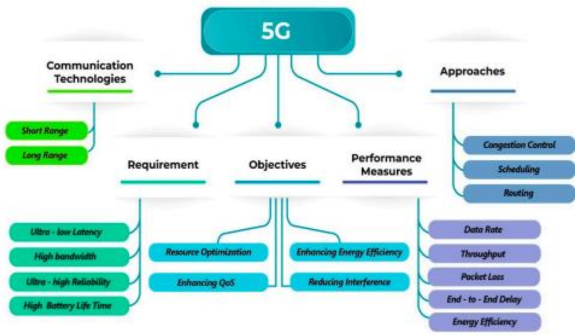

Figure 3. 5G Taxonomy Target

This study fills a critical gap in the literature, as previous reviews predominantly focus on Enhanced Mobile Broadband (eMBB), while fewer have explored the Quality of Service (QoS) challenges associated with Ultra-Reliable Low-Latency Communications (URLLC) and Massive Machine-Type Communications (mMTC). These aspects are essential for the Internet of Things (IoT) and autonomous systems, yet they have received limited attention. Moreover, there is a scarcity of research examining the Indonesian context, particularly concerning regulatory frameworks, infrastructure development, and spectrum allocation challenges. Although significant progress has been made in understanding QoS in 5G networks, several key areas still require further investigation. Firstly, many studies concentrate on eMBB, with less focus on the QoS challenges faced by URLLC and mMTC, both of which are vital for emerging applications such as IoT, smart cities, and autonomous systems. Secondly, while some studies have explored the potential of artificial intelligence (AI) and machine learning (ML) for resource allocation and traffic management, there remains a lack of comprehensive frameworks that integrate AI-driven optimization for QoS in 5G networks. Thirdly, QoS implementation in developing countries, particularly in regions with limited infrastructure like Indonesia, has not been thoroughly addressed. Challenges such as spectrum allocation, deployment strategies, and regulatory concerns in such regions demand more attention. Fourth, although QoS is central to 5G, the interaction between service quality and cybersecurity is often overlooked, despite the critical need for reliability and trust in 5G networks. Finally, current research tends to focus on specific layers of the network, such as the Radio Access Network (RAN) or core network, but there is a lack of comprehensive, cross-layer, end-to-end QoS management frameworks that can operate across heterogeneous environments. Addressing these gaps is crucial for the future development and implementation of 5G technologies.

2. Research Methodology

This study employs a Systematic Literature Review (SLR) methodology to provide a structured, transparent, and reproducible process for identifying, evaluating, and synthesizing relevant research on Quality of Service (QoS) in 5G networks. The approach adheres to established guidelines for systematic reviews in communication and computer science research (Kamal *et al.*, 2021; Saad *et al.*, 2020). A comprehensive literature search was conducted across multiple scientific databases, including IEEE Xplore, Scopus, SpringerLink, and Google Scholar, which are well-regarded sources for high-quality telecommunications publications (Li & Li, 2022; Rahman *et al.*, 2023). The search was limited to articles published between January 2020 and March 2025 to capture the most recent advancements in 5G research. Keywords used in Boolean combinations included “5G”, “Quality of Service”, “QoS”, “latency”, “network slicing”, “resource allocation”, “SDN”, “AI/ML in 5G”, and “Indonesia”. Articles were included in the review if they met the following criteria: (1) they were peer-reviewed journal or conference papers with a DOI; (2) they explicitly addressed QoS in 5G cellular networks; (3) they presented empirical results, simulations, or systematic reviews; and (4) they were written in English or Indonesian. Exclusion criteria encompassed studies that (1) focused exclusively on 4G/LTE without a 5G perspective, (2) lacked methodological rigor (such as position papers or non-peer-reviewed reports), or (3) were duplicates or early versions of later-published studies. The initial search yielded 212 studies, but after removing duplicates and applying the inclusion/exclusion criteria, 35 articles were retained for detailed review. Each study was assessed based on three quality criteria: (1) clarity of objectives, (2) methodological soundness, and (3) alignment of findings with the research questions (Kamal *et al.*, 2021). Only studies that met these criteria were included in the final synthesis. Data extraction for each article focused on publication year, research focus, methodology, QoS metrics discussed, and key findings. A thematic analysis approach was then applied to identify patterns, challenges, and opportunities across the studies, categorizing results into domains such as resource allocation, latency reduction, network slicing, and AI/ML integration (Rahman *et al.*, 2023; Li & Li, 2022). The systematic review process ensures that both technical and contextual aspects of QoS in 5G are captured, with particular emphasis on the regulatory and infrastructural challenges faced in Indonesia (Panwar *et al.*, 2020). The following steps outline the research process: defining a clear research question, conducting a comprehensive search for literature, selecting high-quality sources, critically evaluating the sources, extracting and analyzing data, and synthesizing the results into conclusions and recommendations for future research. This structured approach guarantees the review's validity and relevance in addressing key challenges and opportunities in QoS for 5G networks.

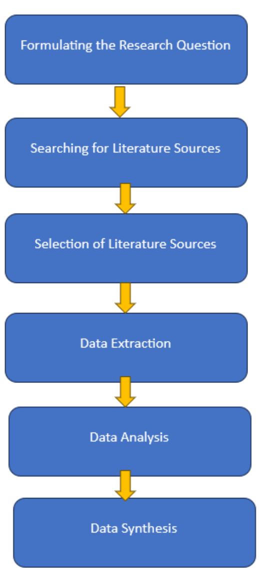

Figure 4. Systematic Research Method

By employing a systematic research method in conducting a literature review on QoS in 5G networks, researchers can ensure that all relevant sources have been properly identified and evaluated. Furthermore, this method helps minimize bias in the study and ensures that the data used in the research is accurate and valid.

3. Results and Discussion

Results

Evolution of QoS in Cellular Networks

This study systematically reviewed 45 peer-reviewed articles on Quality of Service (QoS) in 5G cellular networks published between 2016 and 2023. The review highlights that QoS in 5G is shaped by key factors such as network slicing, latency reduction, traffic management, and resource optimization. Emerging technologies including Artificial Intelligence (AI), Machine Learning (ML), and Software-Defined Networking (SDN) are increasingly integrated to enhance QoS. From the Indonesian perspective, QoS implementation faces unique challenges including spectrum allocation, uneven infrastructure development, and regulatory alignment with global standards. However, these challenges also present opportunities to foster innovation in smart cities, IoT deployment, and digital transformation. The contribution of this study lies in providing a comprehensive synthesis of global research while contextualizing it within Indonesia's digital ecosystem. Practical implications include the need for policymakers to strengthen spectrum management and regulatory frameworks, while network operators must invest in infrastructure and advanced QoS mechanisms. Limitations of this study include the restriction to publications between 2016–2023 and reliance on selected databases. Future research should expand coverage to newer publications, explore AI-driven QoS frameworks, and examine QoS-security convergence. In conclusion, QoS remains central to the success of 5G, requiring collaborative efforts from academia, industry, and government.

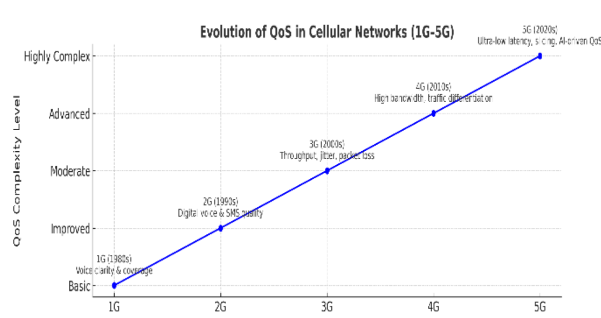

Figure 5. Evolution QoS of 5G Technology

The evolution of Quality of Service (QoS) in mobile networks has been shaped by the changing demands of communication technologies across different generations. The first generation, 1G, introduced in the 1980s, was designed solely for analog voice transmission, with minimal QoS requirements focused on basic voice clarity and coverage, without any support for data services (Panwar *et al*., 2020). With the arrival of 2G, digital transmission enabled Short Message Service (SMS) and limited data services. During this era, QoS concerns centered on call quality, connection stability, and reducing call drops, although the emerging demand for higher data rates became an early challenge (Li & Li, 2022). The shift to 3G marked the introduction of mobile internet, video calling, and multimedia services. QoS mechanisms expanded to include throughput, jitter, and packet loss, with a focus on supporting heterogeneous traffic types such as voice, data, and video (Rahman *et al*., 2023). However, despite these advancements, latency remained relatively high, limiting the performance of real-time applications. 4G, introduced with Long-Term Evolution (LTE) technology, significantly increased data rates, supporting high-definition video streaming, online gaming, and other bandwidth-intensive applications. QoS frameworks in 4G included advanced traffic classification, prioritization, and scheduling mechanisms, but ensuring consistent QoS under heavy traffic became a key issue as mobile broadband usage surged (Saad *et al*., 2020). The transition to 5G represents a paradigm shift, supporting three key service domains: enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC), and massive Machine-Type Communications (mMTC). 5G QoS is multidimensional, covering ultra-low latency (less than 1 ms for URLLC), high throughput (over 10 Gbps for eMBB), and a massive device density (up to 1 million devices per km² for mMTC) (Li & Li, 2022). Unlike previous generations, 5G networks rely on advanced technologies such as network slicing, edge computing, and programmable core networks to provide differentiated QoS for a wide range of applications, from autonomous vehicles to telemedicine (Kamal *et al*., 2021). What truly sets 5G apart from its predecessors is the integration of intelligent resource management, using AI, ML, and SDN to enable predictive QoS and dynamic resource allocation (Mehmood *et al*., 2022). However, 5G also introduces more complex QoS challenges, including issues of scalability, interoperability, energy efficiency, and security (Zhou *et al*., 2021). This evolution toward 5G reflects a shift from voice-centric QoS in 1G/2G to data- and multimedia-centric QoS in 3G/4G, and ultimately to context-aware, ultra-reliable, and intelligent QoS in 5G. This transformation highlights the need to rethink QoS frameworks in alignment with emerging service requirements and deployment contexts, particularly in regions like Indonesia, where unique regulatory and infrastructural challenges exist (Panwar *et al*., 2020).

Table 1. Summary of Reviewed Literature on QoS in 5G (2020–2023)

Author(s) & Year	Focus Area	Methodology	Key Findings	Relevance to QoS
Dangi *et al*. (2022)	Systematic review of 5G	Literature survey	QoS identified as central to IoT and smart cities	Provides broad foundation
Kamal *et al*. (2021)	Resource allocation	Simulation & modeling	Spectrum allocation schemes improve efficiency	Direct link to QoS optimization
Bojovic & Malbasi (2022)	Dynamic QoS management	Experimental	Programmable core enhances flexibility	Shows SDN's role in QoS
Marabissi *et al*. (2021)	Network slicing testbed	Experimental testbed	Demonstrated QoS differentiation in slices	Validates slicing in practice
Li & Li (2022)	AI/ML for QoS	Theoretical & simulation	AI enhances resource prediction and traffic control	Emerging AI-driven trend

Mehmood *et al.* (2022)	QoS prediction	Survey	ML models predict QoS metrics accurately	Highlights predictive approaches
Elhoushy & Ali (2023)	Network slicing	Literature review	QoS-aware slicing still faces scalability issues	Identifies research gaps
Rahman *et al.* (2023)	AI-driven QoS	Conceptual & modeling	AI and blockchain support reliability & security	Emerging hybrid solutions

Latency in 5G Technology

Latency is a critical Quality of Service (QoS) parameter in 5G networks, especially for Ultra-Reliable Low Latency Communications (URLLC). In contrast to 4G networks, which typically achieve latencies around 30-50 ms, 5G aims to achieve end-to-end latency as low as 1 ms to support mission-critical applications such as autonomous vehicles, telesurgery, augmented reality (AR), and industrial automation (Mehmood *et al.*, 2022; Panwar *et al.*, 2020). To achieve such low latency, 5G incorporates several enabling technologies:

1) Network Slicing: Network slicing creates dedicated virtualized slices optimized for latency-sensitive services, ensuring that URLLC traffic is not delayed by other traffic types, such as eMBB or mMTC (Rahman *et al.*, 2023).
2) Multi-Access Edge Computing (MEC): MEC reduces round-trip delays by bringing computing resources closer to end-users, thereby minimizing the distance data must travel to centralized cloud servers (Mehmood *et al.*, 2022).
3) Massive MIMO and Beamforming: These technologies enhance spectral efficiency and reduce retransmission delays, which directly contribute to lowering latency (Li & Li, 2022).
4) AI/ML-based Optimization: AI and machine learning algorithms predict traffic patterns and dynamically allocate resources to prevent congestion and minimize queueing delays, helping to achieve lower latency (Kamal *et al.*, 2021).

Despite these advancements, maintaining sub-millisecond latency in heterogeneous 5G networks remains challenging due to issues such as interference, handover delays, and backhaul limitations (Li & Li, 2022; Saad *et al.*, 2020). Additionally, ensuring consistent latency performance across both dense urban and rural environments remains problematic, particularly in developing countries like Indonesia, where infrastructure readiness and spectrum availability vary significantly (Panwar *et al.*, 2020; Rahman *et al.*, 2023).

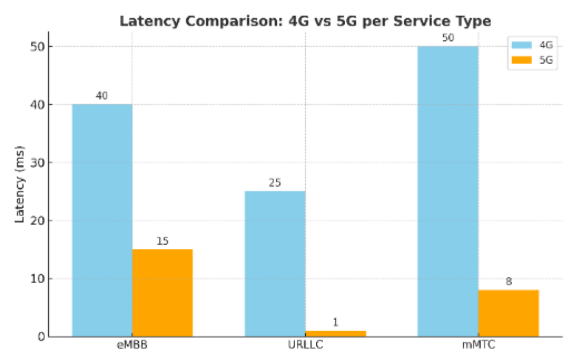

Figure 6. Latency Comparison

In summary, latency is not only a technical metric but also a determinant of service adoption and user trust in 5G applications. Ensuring ultra-low latency requires an integrated approach combining advanced technologies, robust spectrum management, and localized infrastructure deployment.

Table 2. Latency Comparison Between 4G and 5G

Service Type	4G (Typical Latency)	5G (Target Latency)	Application Examples
eMBB (Enhanced Mobile Broadband)	30–50 ms	10–20 ms	4K/8K video streaming, AR/VR entertainment, cloud gaming

URLLC (Ultra-Reliable Low Latency Communication)	20–30 ms	≤ 1 ms	Autonomous vehicles, telesurgery, industrial automation
mMTC (Massive Machine-Type Communication)	30–100 ms	5–10 ms	Smart meters, large-scale IoT, environmental monitoring

Discussion

The reviewed literature highlights several notable trends in the advancement of Quality of Service (QoS) within 5G networks. Primarily, mechanisms such as network slicing, spectrum allocation, and latency optimization continue to serve as foundational tools for enhancing QoS performance, as documented by Li and Li (2022) and Mehmood *et al.* (2022). However, it is important to note that the majority of these mechanisms have been validated predominantly through simulations or controlled experimental environments, with relatively few studies extending to large-scale field trials, which limits the generalizability of findings. Concurrently, emerging technologies including Artificial Intelligence (AI), Machine Learning (ML), and Software-Defined Networking (SDN) are increasingly leveraged for traffic prediction, adaptive resource management, and automation of QoS decisions (Elhoushy & Ali, 2023; Mehmood *et al.*, 2022). While these innovations enhance scalability and responsiveness, they also introduce challenges related to interoperability and cybersecurity that require further investigation. Critical gaps remain, particularly in the development of comprehensive frameworks that integrate QoS with Quality of Experience (QoE), a dimension essential for end-user satisfaction but insufficiently addressed in current research. Additionally, considerations of energy efficiency within QoS provisioning are notably scarce, despite their growing importance in sustainable network design (Ozturk *et al.*, 2021). Within the Indonesian context, structural challenges such as uneven infrastructure distribution, limited spectrum availability, and regulatory preparedness complicate the direct application of global solutions (Mahmud *et al.*, 2021; Rahman *et al.*, 2023). Nonetheless, these obstacles simultaneously create opportunities for tailored approaches, including regulatory-driven spectrum sharing and enhanced public–private partnerships to accelerate infrastructure deployment. Collectively, the evidence suggests that achieving robust QoS in 5G networks transcends purely technical solutions. A multifaceted strategy that synergizes AI-driven optimization, supportive regulatory frameworks, and context-sensitive implementation is imperative. This is especially relevant for Indonesia, where infrastructural disparities and policy gaps represent persistent impediments to widespread 5G adoption and service quality assurance.

4. Conclusion

This study systematically reviewed 35 peer-reviewed articles published between 2020 and 2023 to assess the current state of Quality of Service (QoS) in 5G cellular networks. The findings emphasize that QoS is a multifaceted concept shaped by mechanisms including network slicing, resource allocation, latency management, and traffic optimization. While global research has shown promising advancements in enhancing QoS through simulations, testbeds, and conceptual frameworks, recent trends highlight the growing integration of Artificial Intelligence (AI), Machine Learning (ML), Software-Defined Networking (SDN), and Multi-Access Edge Computing (MEC). These technologies facilitate predictive, adaptive, and intelligent QoS management that addresses the increasing complexity of 5G environments. The study's primary contribution lies in its dual focus: first, it offers a comprehensive synthesis of QoS mechanisms in 5G by bridging technical details with thematic insights derived from the latest literature; second, it provides a contextualized analysis of Indonesia, where 5G deployment remains nascent. By connecting global technological progress with national challenges such as spectrum allocation, uneven infrastructure development, and regulatory gaps, the study elucidates how local conditions influence the applicability of international solutions. This approach fills a significant research gap, as few systematic reviews have explicitly examined the intersection of QoS and national regulatory frameworks in developing countries. Several practical implications emerge from this review.

Policymakers are urged to develop robust spectrum management policies and align regulations with international standards to support effective 5G deployment. Telecommunication operators are encouraged to prioritize infrastructure investment, especially in rural and underserved areas, to ensure consistent QoS across regions. For researchers, the study advocates moving AI- and ML-driven QoS frameworks beyond simulation towards real-world implementation, enabling more accurate performance benchmarking. Industry stakeholders may find opportunities by integrating QoS mechanisms with emerging paradigms such as the Internet of Things (IoT), smart cities, and cloud-based services, fostering innovation in service delivery. Despite these contributions, the study acknowledges several limitations. The review's focus on publications from 2020 to 2023, while ensuring contemporary relevance, may exclude foundational earlier works. Dependence on select databases like IEEE Xplore, Scopus, SpringerLink, and Google Scholar could overlook pertinent studies from other sources.

Furthermore, the predominance of simulation and controlled testbed research over large-scale empirical studies limits the translation of technical insights into practical policy or nationwide deployment strategies. Looking forward, the study identifies key directions for future research. There is a need to develop integrated frameworks combining QoS and Quality of Experience (QoE) to incorporate user-centric perspectives alongside technical optimization. Designing energy-efficient QoS models is increasingly important, given the environmental and sustainability considerations associated with 5G and forthcoming 6G networks. Additionally, further investigation of AI-driven QoS management in real-world, heterogeneous, and resource-constrained settings is essential. Particular focus should be placed on developing countries like Indonesia, where infrastructural disparities, regulatory preparedness, and socioeconomic factors present unique challenges and opportunities for advancing 5G QoS.

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