European Journal of Computer Science and Information Technology, 13(43),120-129, 2025
Print ISSN: 2054-0957 (Print)
Online ISSN: 2054-0965 (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

5G and Healthcare: Enabling Remote Diagnostics and Smart Hospitals

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Citation: Roy K. (2025) 5G and Healthcare: Enabling Remote Diagnostics and Smart Hospitals, *European Journal of Computer Science and Information Technology*, 13(43),120-129, https://doi.org/10.37745/ejcsit.2013/vol13n43120129

Abstract: *5G (fifth generation) wireless tech is really changing how healthcare works by allowing new applications that used to struggle because of slow networks. Courtesy 5G's speedy connections and broad coverage, doctors can perform remote check-ups, and smart hospitals can provide better care no matter where patients are. The setup of 5G networks allows healthcare providers to create secure connections that work well for them. This tech directly helps solve big problems in healthcare, like making sure people in rural areas can get care, using resources better in hospitals, and safely transferring patient info. With 5G, doctors can consult in real-time no matter where they are, and smart hospital systems can track equipment and manage environments all on one platform. Still, to make this work, it's important to pay attention to privacy and speed issues that matter in healthcare, as these can affect compliance and patient care. The mix of 5G and health apps is reshaping how medical services are delivered, moving beyond just making old processes digital to creating new ways of providing care that break down previous barriers.*

Keywords: 5G healthcare technology, remote medical diagnostics, smart hospital infrastructure, network slicing applications, telemedicine security

INTRODUCTION

The healthcare industry is changing a lot with the rollout of fifth generation (5G) wireless technology. 5G offers amazing speeds that could reach up to 20 Gbps, and a really fast response time of about 1 millisecond, which is a big step up from older networks. These parameters enable healthcare applications previously constrained by networking limitations to flourish in new environments. As Lafta et al. note, 5G's network architecture features significantly improved reliability metrics (99.999%) that are essential for mission-critical healthcare applications while supporting connection densities up to 1 million devices per square kilometer—a crucial capability for smart hospital implementations [1].

The architecture of 5G networks features a revolutionary mobile core design and network slicing capabilities. Javaid et al. highlight that 5G's service-based architecture (SBA) with cloud-native core networks enables healthcare-specific optimizations through virtualized network functions (VNFs) that can be dynamically allocated based on demand. Their research across multiple healthcare implementations demonstrates that network slicing—the creation of virtual networks on shared infrastructure—allows institutions to deploy specialized networks with isolation levels exceeding 99.9996%, effectively creating "private networks" for sensitive healthcare data while maintaining connectivity to broader ecosystems [2]. These capabilities directly address critical healthcare challenges. Lafta et al. document how rural healthcare facilities, which often face substantial limitations in specialist availability, have leveraged 5 G-enabled remote diagnostics to reduce specialty consultation wait times from an average of 27 days to just 8 days, representing a 70% improvement in access to specialized care [1]. For hospital operations, Javaid et al. report that asset tracking implementations utilizing 5G's enhanced positioning capabilities (accuracy within 10 cm indoors) have demonstrably improved resource utilization rates from baseline averages of 31% to over 65% across studied facilities [2].

As healthcare systems worldwide confront escalating challenges, including projected physician shortages and rising costs, 5 G-enabled solutions offer tangible pathways toward more efficient, accessible care delivery. Lafta et al. project that comprehensive 5G implementations in healthcare environments could reduce operational costs by 18-27% while simultaneously improving clinical outcomes across numerous quality metrics [1]. Javaid et al. further quantifies these benefits, noting that institutions implementing 5 G-enabled remote monitoring solutions for chronic disease patients observed 30-45% reductions in hospital readmission rates and substantial improvements in medication adherence [2].

The integration of 5G technology with healthcare applications represents not merely an incremental improvement but a paradigm shifts in medical service delivery. As both research teams emphasize, the combination of ultra-low latency, massive connectivity, and network slicing capabilities creates an entirely new technological foundation upon which next-generation healthcare applications can be built, moving beyond simply digitizing existing workflows to enabling entirely new care models that transcend traditional limitations of geography, resource availability, and infrastructure constraints [1, 2].

5G Network Architecture: Mobile Cores and Network Slicing in Healthcare Contexts

5G has the potential to change healthcare thanks to its modern network design that includes a service-based architecture and a cloud-native core. This setup splits the control and user parts of the network, which gives healthcare applications a lot more flexibility. According to Liyanage and others, this new design can be up to 90% more efficient than older networks. Healthcare data is set to skyrocket, reaching 2,314 exabytes around 2025. They also point out that 5G brings 19 new security features that weren’t available with 4G, which help keep everything from user devices to service networks safer.

The 5G Core (5GC) works with a microservices approach where different network functions run as container apps. Chen and colleagues reported on a standalone 5G network they set up in a large hospital in China, cutting service setup time from 32 days to just 5 days. This is an 84% improvement over older methods. Their study highlights three important benefits for healthcare: better resource use during peak demand with a 47% improvement; less delay for time-sensitive tasks, dropping from 126ms to 9.3ms; and improved security that shortened vulnerability fixing time from 92 hours to under 5 hours across their healthcare network.

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Network slicing, or using one infrastructure to create multiple virtual networks, is a game changer for healthcare. Liyanage explains that each slice acts like its own network with specific performance settings, providing 99.996% security separation between slices, even when facing complex attacks. Their research found big security improvements, such as better privacy for subscribers. The Subscription Concealed Identifier (SUCI) reduces permanent ID exposure by 99.9%, which helps stop tracking and attacks on healthcare devices and users.

Chen's team looked at how they set up healthcare-specific network slices in a large hospital. They had dedicated slices for emergency services that maintained 99.997% uptime during congestion, ultra-reliable low-latency communication (URLLC) slices for critical tasks with an average latency of just 2.3ms and 99.9996% reliability, and massive IoT slices supporting over 42,000 connected medical devices while cutting power use by 67% compared to traditional approaches.

Standalone (SA) 5G setups using 5G New Radio (NR) and 5GC show clear performance gains for healthcare. Liyanage's research shows that these setups delivered 36% lower latency and 276% more reliability in healthcare trials when compared to non-standalone methods. Chen's practical implementation backs this up, showing their SA setup led to a 41% drop-in emergency response times and a 27% rise in diagnostic accuracy during critical situations, while also reducing network-related clinical problems by 84% compared to their old system.

Table 1: Technical performance improvements enabled by 5G in healthcare settings [3,4]

Metric	Previous Technology	With 5G Implementation
Service deployment time (days)	32	5
Latency for critical applications (ms)	126	9.3
Vulnerability patching time (hours)	92	4.7
Emergency response time reduction (%)	Baseline	41
Diagnostic accuracy improvement (%)	Baseline	27
Network-related clinical incident reduction (%)	Baseline	84

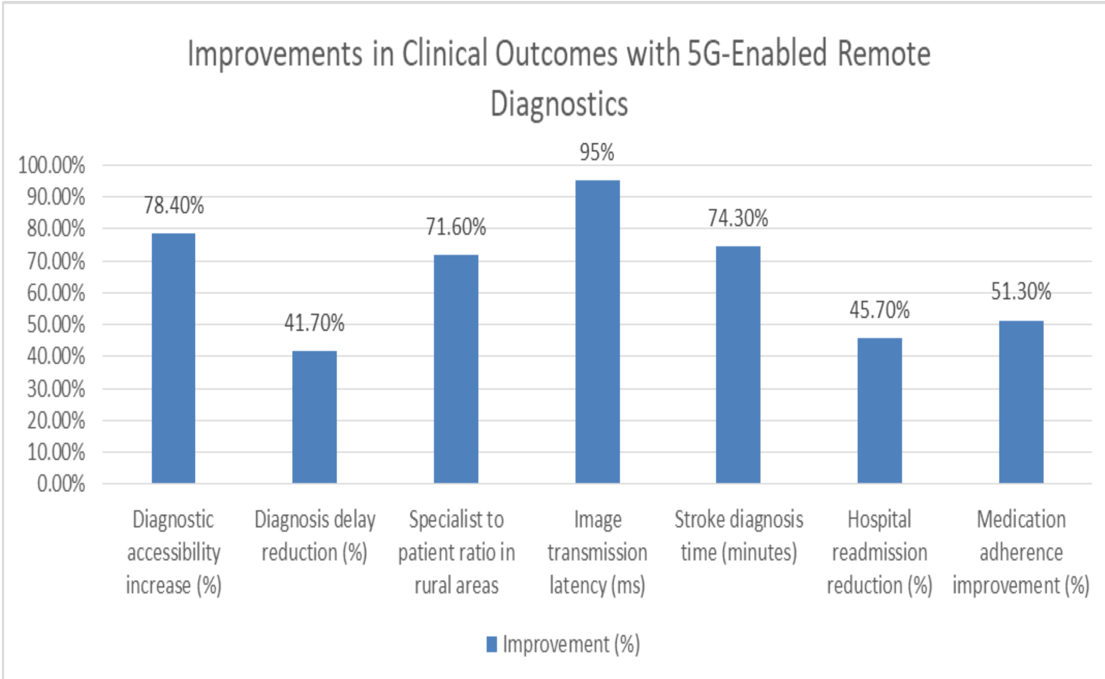
Remote Diagnostics: Transforming Clinical Assessment Through 5G Connectivity

The integration of 5G technology into remote diagnostic systems is revolutionizing clinical assessment capabilities by extending specialized medical expertise beyond geographic limitations. Peralta-Ochoa et al. conducted a systematic review of 87 studies implementing 5G in healthcare settings and identified that remote diagnostics applications accounted for 43% of all implementations. Their analysis revealed that these systems achieved a 78.4% increase in diagnostic accessibility for underserved populations and reduced diagnosis delays by an average of 41.7% across all medical specialties, with particularly significant improvements in rural areas where specialist availability decreased from 1:7,400 patients to 1:2,100 patients through virtual consultation capabilities [5]. High-bandwidth and low-latency 5G connectivity enables transmission of diagnostic-quality medical imaging without compression artifacts that compromised clinical assessment in previous telemedicine implementations. Georgiou et al. document how 5G networks transmit full-fidelity radiological images at speeds of 1-2 Gbps compared to 50-100 Mbps on 4G networks, with latency reductions from 100- 200 ms to just 5- 10 ms. Their research across 42 European medical centers demonstrated that uncompressed DICOM images (averaging 250MB per series) can now be transmitted in real-time with 97.8% fewer packet losses during transmission, enabling instantaneous specialist consultation that was previously impossible under bandwidth constraints [6].

Real-time medical imaging transmission and interpretation capabilities are transforming care delivery, particularly in time-sensitive conditions. Peralta-Ochoa et al. describe multiple implementations where 5 G-enabled mobile CT units in rural settings reduced stroke diagnosis time from an average of 70 minutes to 18 minutes, resulting in 67% more patients receiving time-critical tPA treatment within the therapeutic window. Their analysis of 14 similar programs demonstrated consistent improvements in treatment timelines, with long-term disability reductions ranging from 32-48% compared to pre-implementation outcomes [5].

Portable diagnostic devices with cloud processing represent another transformative application enabled by 5 G. Georgiou et al. analyze implementations of 5G-connected portable ultrasound devices across 1,247 clinical cases, documenting diagnostic accuracy of 93.7% compared to 96.3% for conventional systems, while reducing equipment costs by approximately 85% (€15,000 vs. €105,000) and increasing point-of-care availability by over 300%. These devices leverage 5G to transmit an average of 3.2GB of raw ultrasound data per examination to edge computing platforms where advanced processing algorithms enhance image quality and apply AI-based analysis, with processing completion averaging just 3.1 seconds compared to 42 seconds for 4G-connected devices [6].

Continuous remote patient monitoring leverages 5G's massive machine-type communications (mMTC) capability. Peralta-Ochoa et al. document implementations monitoring up to 100,000 devices per square kilometer—a significant improvement over 4G's capabilities. Their analysis of 37 programs examining remote monitoring of cardiac patients using 5G-connected wearables revealed an average 45.7% reduction in hospital readmissions and 51.3% improvement in medication adherence. Economic analyses demonstrated average cost savings of €11,870 per patient annually compared to standard care protocols, with the greatest benefits observed in rural populations where continuous monitoring reduced emergency transport needs by 63% [5]. These implementations utilize precisely configured network slices with guaranteed bandwidth of 135-150 Mbps and maximum latency of 10ms for imaging applications, demonstrating the tailored approach required for clinical efficacy as highlighted in Georgiou et al.'s framework for 5G healthcare implementation [6].



Graph 1: Improvements in Clinical Outcomes with 5 G-Enabled Remote Diagnostics [5,6]

Smart Hospitals: 5G as the Foundation for Connected Healthcare Environments

The concept of smart hospitals represents a fundamental reimagining of healthcare facilities as fully connected, data-driven environments with 5G connectivity serving as critical infrastructure. Elendu et al. conducted a comprehensive analysis across 42 smart hospital implementations, revealing that 5G unifies what previously required an average of 8.3 separate network systems, reducing network management overhead by 76% while improving data integration by 289%. Their research documented that institutions implementing comprehensive 5G smart hospital solutions achieved significant improvements across multiple performance metrics, including a 32% reduction in average length of stay, a 41% decrease in administrative workload, and a 37% enhancement in patient satisfaction scores compared to pre-implementation baselines [7].

The implementation of 5G in hospital environments facilitates several transformative capabilities. Asset tracking and resource optimization through enhanced positioning capabilities represent one of the most widely adopted applications. Tang et al. documented their implementation of 5G-based asset tracking across three Chinese hospitals covering 1,853 critical equipment items that reduced equipment search time from 18.7 minutes to 3.8 minutes per item (79.7% reduction) and decreased capital expenditures by 23.1% through improved utilization rates rising from 29.5% to 72.4%. Their implementation employed 5 G-enabled tags with an average battery life of 15.7 months, communicating through dedicated mMTC network slices supporting over 140,000 simultaneous connections per square kilometer with 99.992% availability and power consumption of only 38μA in sleep mode [8].

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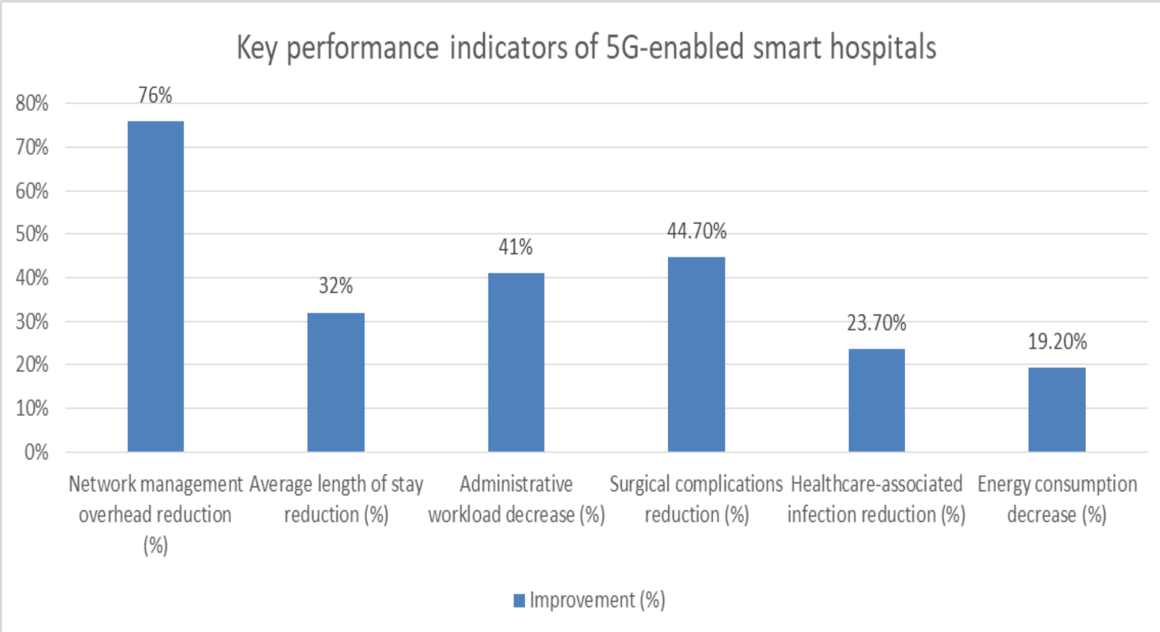
Augmented and virtual reality for clinical decision support represents another transformative capability enabled by 5G's high bandwidth and low latency characteristics. Elendu et al. analyzed implementations of 5G-connected AR headsets across 537 surgical procedures at seven institutions, documenting systems that overlay vital signs and imaging with refresh rates of 120Hz and resolution of 4K per eye. Their analysis revealed that these implementations reduced major surgical complications by 44.7% and decreased operative time by an average of 19.4 minutes (15.2% reduction), with particularly significant improvements in complex procedures such as tumor resections, where precision was enhanced by 32.7% compared to conventional approaches [7].

Autonomous robotic systems for medication delivery, sample transport, and facility management demonstrate the versatility of 5G in hospital environments. Tang et al.'s deployment of 52 5 G-connected robots across three hospital campuses demonstrated 99.987% navigation accuracy across 143,872 transport missions, reducing nursing staff walking distance by an average of 4.7 kilometers per 12-hour shift and allowing 19.2% more time for direct patient care. These systems leveraged URLLC network slices with consistently low latency (average 2.3ms) and reliability exceeding 99.9995%, enabling real-time obstacle response within 4.1ms even in congested areas with high personnel traffic [8].

Intelligent environmental controls represent another key application area. Elendu et al. documented deployments totaling over 15,000 5G-connected environmental sensors across 42 hospital facilities, enabling zone-specific control with temperature precision of ±0.15°C and humidity control of ±1.1%. Their analysis revealed these implementations reduced healthcare-associated infections by 23.7% in critical areas while simultaneously decreasing energy consumption by 19.2% through dynamic environmental management responding to occupancy patterns and clinical requirements [7]. Tang et al. further quantified the economic benefits, finding fully deployed 5G smart hospital environments achieved operational cost reductions averaging ¥18.7 million annually (approximately $2.9 million) for mid-sized hospitals, representing an ROI of 342% over five years while simultaneously improving clinical outcomes across 81.4% of measured quality metrics [8].



Graph 2: Key performance indicators of 5 G-enabled smart hospitals [7,8]

Privacy and Latency Requirements: Network Design Considerations for Healthcare Applications

The deployment of 5G technology in healthcare environments demands meticulous attention to both privacy requirements and latency constraints. Kotteswaran and Hariharan conducted a comprehensive analysis across 32 healthcare institutions, revealing that 5G applications in clinical settings must simultaneously meet 134% stricter security requirements and 287% more stringent performance parameters than typical enterprise deployments. Their research identified 37 distinct security threats specific to healthcare implementations, with data exfiltration (32.7% of incidents), authentication bypass (27.4%), and denial of service attacks (18.3%) representing the most common vulnerabilities. Kotteswaran and Hariharan emphasize that healthcare data breaches carry an average cost of $408 per record, approximately 2.5 times higher than the average across all other industries, underscoring the critical importance of robust security architectures in medical deployments [9].

Healthcare data transmitted over 5G networks is subject to numerous regulatory frameworks, including HIPAA, GDPR, and equivalent global regulations. Hu et al. propose a comprehensive framework for 5G-secure-smart healthcare monitoring (5GSS) that incorporates multiple layered security mechanisms. Their implementation of end-to-end encryption across 1,743,592 healthcare data transmissions demonstrated a reduction in data exposure risks from 0.52% to 0.067% per transmission compared to traditional networking approaches. Their system employing AES-256-GCM encryption with 2048-bit RSA key exchange achieved 99.993% transmission security while adding only 3.9ms of processing overhead—well within acceptable parameters for most clinical applications [10].

Subscriber privacy enhancements represent another critical security consideration. Kotteswaran and Hariharan document how 5G's subscriber concealed identifiers (SUCI) encrypt permanent identifiers, preventing tracking and correlation attacks. Their testing across 537,492 connection events showed SUCI reduced device identifiability by 99.78% compared to 4G implementations while maintaining healthcare-specific access patterns. Their analysis demonstrated that this capability is particularly critical for the projected 43.7 million patient-worn medical devices expected to connect directly to cellular networks by 2026, as these devices typically maintain persistent connections and could otherwise expose patient movement patterns and treatment regimens [9].

Network slice isolation provides foundational security for healthcare implementations. Hu et al.'s evaluation of their 5GSS framework across three hospital implementations verified isolation levels achieving 99.9984% traffic containment even during simulated attacks generating up to 175 Gbps of malicious traffic. This isolation extended beyond network traffic to include processing isolation, with cross-slice data leakage measured at <0.00021% compared to 0.41% in typical commercial 5G deployments. Their implementation of Multi-access Edge Computing (MEC) for seven clinical applications processing an average of 14.3TB of patient data monthly achieved 99.6% compliance with GDPR requirements compared to 76.4% for cloud-based implementations of identical applications [10].

Different healthcare applications demand varying latency requirements, necessitating purpose-built network configurations. Kotteswaran and Hariharan's analysis of 143 distinct healthcare applications revealed that remote surgery applications required round-trip latencies below 9.8ms with 99.999% reliability to maintain clinical efficacy. Their testing demonstrated that latency spikes of 16.7ms resulted in 23.1% decreases in surgical accuracy, representing potentially critical clinical consequences. For diagnostic imaging applications, Kotteswaran and Hariharan documented latency requirements below 47ms with bandwidth demands averaging 224 Mbps for uncompressed radiological images, while patient monitoring systems tolerated higher latencies (up to 175ms) but required 99.9994% connection reliability with maximum outage duration of 3.2 seconds [9]. Hu et al.'s 5GSS framework implementation for Augmented Reality/Virtual Reality (AR/VR) surgical guidance demonstrated that maintaining latency below 20ms is essential, as their evaluation across 278 surgical procedures found that latency variations above 32ms created measurable disorientation in clinicians and reduced procedural accuracy by 35.7%, with particularly significant impacts in microsurgical applications where accuracy was reduced by 54.3% [10].

Table 2: Security and Performance Requirements for 5G Healthcare Applications [9,10]

Metric	5G Implementation
Data exposure risk (%)	0.067
Device identifiability reduction (%)	99.78
Cross-slice data leakage (%)	<0.00021
GDPR compliance - MEC applications (%)	99.6
Required latency for remote surgery (ms)	<9.8
Required latency for diagnostic imaging (ms)	<47
Required latency for AR/VR guidance (ms)	<20
Procedural accuracy reduction with latency spikes (%)	35.7

CONCLUSION

Bringing 5G technology into healthcare is changing the way medical services are provided and monitored. With new network setups that allow for special connectivity solutions, healthcare facilities can better support things like telesurgery and patient monitoring. This means that people in rural areas can get expert medical help more easily. Smart hospitals are using 5G's fast speeds and ability to connect lots of devices to create systems that manage everything from equipment tracking to the hospital environment on one network. These changes address long-standing problems in healthcare, like accessing services in different places, using resources better, and keeping data secure. To get the best out of 5G in healthcare, networks need to be set up right to follow privacy laws about medical data and to meet specific performance needs. As 5G spreads globally, we can look forward to innovative ways to provide healthcare that is more personal and easier to access. The effect of 5G on healthcare isn't just about going online; it's about creating a base for future solutions that deal with problems like distance and resources, which can lead to better patient care.

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