

REVIEW ARTICLE

The Impact of 5G on Global Connectivity

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ABSTRACT:

5G technology is revolutionizing global connectivity by delivering unprecedented speed, ultra-low latency, and the capacity to connect a massive number of devices simultaneously. This fifth generation of mobile networks significantly upgrades 4G by enabling superfast broadband, ultrareliable low-latency communication, and massive machine-type communications, which collectively support the growing demands of the Internet of Things (IoT), smart cities, autonomous vehicles, and advanced industrial automation. Industries such as manufacturing, healthcare, transportation, and agriculture will particularly benefit from 5G through increased automation, improved efficiency, and real-time data analytics. For example, 5G-enabled smart diagnostics in healthcare could prevent millions of medical interventions, while manufacturing will see significant productivity gains from automation and connected devices. Additionally, 5G facilitates better communication, supports innovative business models, and fosters technological advancements like virtual and augmented reality. Despite its transformative potential, 5G deployment requires overcoming challenges related to infrastructure investment, security, and regulatory compliance. Nevertheless, its ability to interconnect people, devices, and systems promises to redefine global connectivity and drive the next wave of digital transformation across multiple sectors.

KEYWORDS: Revolutionizing global connectivity; 5G technology;

1. 1. Introduction

Mobile communication has advanced through five distinct generations since the 1980s, each generation redefining what "connectivity" means for individuals, enterprises, and governments. Where 1G merely digitized voice and 4G/LTE brought mobile broadband and the app economy, fifth-generation (5G) wireless technology represents a qualitative rather than merely incremental leap. Standardized by the 3rd Generation Partnership Project (3GPP), 5G is built around three service pillars — Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communication (URLLC), and Massive Machine-Type Communication (mMTC) — that together allow a single network to simultaneously deliver multi-gigabit consumer video streaming, millisecond-level control-loop latency for safety-critical automation, and connectivity for up to one million devices per square kilometer. This combination of characteristics positions 5G not simply as "faster 4G" but as the

connective infrastructure underpinning the Internet of Things (IoT), smart cities, autonomous vehicles, Industry 4.0, and immersive virtual and augmented reality (VR/AR).

The global significance of this shift is substantial. Industry analyses project that 5G-enabled efficiency, automation, and new digital services could add more than a trillion US dollars to global GDP by 2030, with healthcare, manufacturing, utilities, and transport identified as the largest beneficiary sectors. In healthcare, network-enabled remote diagnostics and monitoring are expected to reduce preventable hospitalizations and interventions at scale; in manufacturing, ultra-reliable low-latency links allow robots and automated guided vehicles to coordinate in real time; in transportation, vehicle-to-everything (V2X) communication is a prerequisite for safe autonomous mobility. Beyond these headline sectors, 5G is also reshaping how businesses design products and services, enabling cloud-based gaming, tactile internet applications, and distributed collaboration through AR/VR that would be infea-

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sible over legacy 4G latency and bandwidth budgets.

Despite this promise, 5G deployment is neither instantaneous nor uniform. Rolling out dense small-cell and millimeter-wave (mmWave) infrastructure requires capital investment far exceeding that of previous generations, spectrum allocation differs by country and regulator, and the same hyper-connectivity that enables new services also expands the attack surface available to malicious actors, particularly as billions of relatively unsecured IoT endpoints join the network. This paper examines the impact of 5G on global connectivity by (i) reviewing the technological building blocks that distinguish 5G from earlier generations, (ii) synthesizing evidence on its cross-sector applications and projected economic contribution, and (iii) critically discussing the infrastructural, security, and regulatory barriers that will determine how quickly and how equitably its benefits are realized worldwide.

2. Literature Review

A substantial body of recent literature has examined the technical foundations that allow 5G to support IoT and smart-city applications at scale. Reviews consistently identify network slicing, edge computing, and enhanced mobile broadband as the core enablers that let a single physical network serve heterogeneous use cases with very different latency, throughput, and density requirements [1], [3]. Multiple studies report that 5G's ultra-low latency — as low as one millisecond in optimized deployments — is what makes mission-critical applications such as remote surgery, autonomous transportation, and industrial automation feasible, since these applications cannot tolerate the 50–200 millisecond latency typical of 4G/LTE [3], [4].

Massive connectivity is the second recurring theme: 5G networks are designed to support on the order of one million connected devices per square kilometer, an order of magnitude

beyond what 4G/LTE architectures can reliably sustain, which is essential given forecasts of tens of billions of connected IoT devices worldwide by the mid-2020s [1], [5]. To meet this density without exhausting licensed spectrum in dense urban areas, several studies propose hybrid architectures that combine 5G with Low-Power Wide-Area Network (LPWAN) technologies for remote or rural coverage, arguing that neither technology alone is sufficient to serve both dense cities and underserved regions cost-effectively [6].

A parallel and rapidly growing literature addresses security. Because 5G's flexibility relies heavily on software-defined networking (SDN) and network function virtualization (NFV), several works argue that the attack surface of 5G-IoT ecosystems is structurally larger than that of earlier, more hardware-centric network generations, and that securing constrained edge devices — such as traffic sensors and roadside units in smart-transportation deployments — requires lightweight, purpose-built cybersecurity frameworks rather than a direct transplant of enterprise IT security practices [2], [7]. Reviews on smart cities similarly flag scalability and interoperability as open engineering challenges, since city-scale IoT deployments must reconcile heterogeneous device vendors, protocols, and data formats across a continuously expanding network [8].

Finally, a body of economic-analysis literature quantifies 5G's expected contribution to global output. Independent industry analyses converge on the finding that healthcare, manufacturing, and utilities will capture the largest share of 5G-driven GDP growth, with estimates of the aggregate global contribution by 2030 ranging from roughly US\$500 billion to US\$1.3 trillion depending on the scope of applications and efficiency gains modeled [9], [10], [11]. Table 1 summarizes representative categories of this literature and situates the present paper's contribution relative to them.

Table 1: Summary of representative prior work on 5G and global connectivity

Research Focus	Key Enabling Concepts	Principal Findings	Ref.
5G–IoT integration for smart cities/self-driving cars	Network slicing, edge computing, eMBB	5G provides the connectivity foundation for diverse IoT ecosystems across sectors	[1]
5G-enabled cybersecurity for smart transportation	Lightweight authentication, anomaly detection	Resource-constrained edge devices need purpose-built, low-overhead security frameworks	[2]
5G and Beyond (B5G) for IoT/smart cities	Network slicing, edge computing, mmWave/Sub-6GHz	Sub-1 ms latency and up to 1 million devices/km ² enable mission-critical applications	[3]
5G network architecture review	Core network, RAN, use-case mapping	Describes core/RAN components and cross-domain use cases (IoT, telemedicine, smart cities)	[4]
5G–IoT connectivity for consumer devices	eMBB, URLLC, mMTC per 3GPP standards	5G unlocks IoT and immersive AR/VR use cases infeasible on 4G/LTE	[5]
Hybrid 5G–LPWAN for smart cities and remote areas	SDN/NFV network slicing, LPWAN integration	Combining 5G with LPWAN improves cost-effective coverage of both dense and remote areas	[6]
5G–IoT interference and optimization challenges	Spectrum interference, network optimization	Seamless 5G–IoT compatibility requires resolving interference and optimization issues	[7]
5G and IoT sustainability/security in smart cities	Layered IoT architecture (perception–network–edge–application–business)	Scalability and interoperability remain open challenges as urban IoT deployments expand	[8]
Global economic impact of 5G	Sectoral GDP modeling	5G projected to add US\$500bn–US\$1.3tn to global GDP by 2030, led by healthcare and manufacturing	[9],[10],[11]
Present study	Synthesis of architecture, applications, economic and regulatory evidence	Unified, cross-sector view of 5G's impact on global connectivity with prioritized challenge areas	This work

3. 3. 5G Architecture and Key Enabling Technologies

Figure 1 depicts the layered architecture through which 5G delivers global connectivity. At the user-equipment layer, smartphones, wearables, IoT sensors, autonomous vehicles, and industrial machines connect to the network with heterogeneous

throughput, latency, and reliability requirements. These devices attach to the 5G Radio Access Network (RAN) through next-generation base stations (gNodeBs), which operate across two principal frequency ranges: sub-6 GHz (FR1), which offers wide-area coverage with substantial throughput improvements over 4G, and millimeter-wave or mmWave (FR2), which uses frequencies above 24 GHz to deliver very high

throughput and low latency over shorter distances, typically in dense urban deployments. Massive Multiple-Input Multiple-Output (Massive MIMO) antenna arrays and beamforming techniques allow each gNodeB to serve many more simultaneous users with directional, adaptive signal paths than legacy sector antennas, substantially increasing spectral efficiency.

Beneath the RAN, the 5G Core Network (5GC) is built on software-defined networking and network function virtualization, allowing operators to implement network slicing — the logical partitioning of a single physical network infrastructure into multiple virtual networks, each tuned to a specific service profile. A network slice supporting eMBB might prioritize throughput for video streaming, while a slice supporting URLLC for a factory floor prioritizes deterministic low latency over raw bandwidth, and a slice supporting mMTC for an agricultural sensor network prioritizes device density and battery efficiency over speed. Multi-access Edge Computing (MEC) complements this by moving compute and storage resources physically closer to the RAN, reducing round-trip latency for applications such as augmented-reality overlays or autonomous-vehicle perception that cannot tolerate the delay of routing data to a distant centralized data center.

Figure 2 situates 5G within the broader evolution of mobile network generations, contrasting peak theoretical data rates and typical latency across 1G through 5G. The chart illustrates the discontinuity between 4G and 5G: while each earlier generational transition delivered roughly an order-of-magnitude improvement in data rate, the jump from 4G to 5G additionally delivers approximately a fifty-fold reduction in typical latency, which is the characteristic that unlocks entirely new application categories — such as remote robotic surgery and V2X coordination — rather than simply making existing mobile-broadband applications faster.

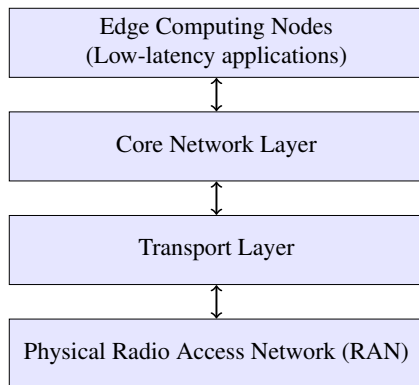


Figure 1: Layered architecture of 5G network enabling global connectivity

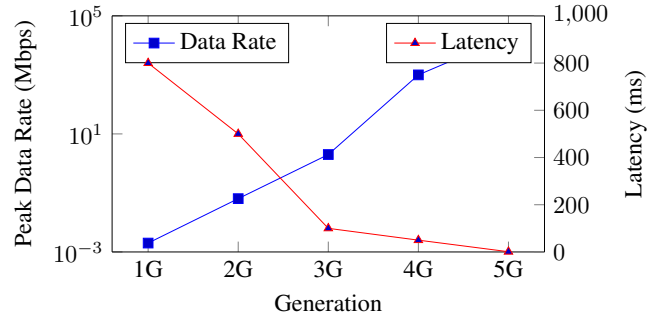


Figure 2: Evolution of mobile network generations — peak data rate and latency

4. 4. Applications Across Sectors

The combination of eMBB, URLLC, and mMTC allows 5G to serve markedly different application domains without deploying separate physical networks for each. In healthcare, 5G supports remote patient monitoring through connected wearables, high-resolution telemedicine consultations, and — in trial deployments — remote-assisted surgical procedures that depend on the network's low, deterministic latency. In manufacturing, 5G-connected robots, automated guided vehicles, and condition-based monitoring sensors enable Industry 4.0 factories to coordinate machinery in real time and detect equipment faults before they cause costly downtime. In transportation, vehicle-to-everything (V2X) communication allows vehicles to exchange position, speed, and hazard information with each other and with roadside infrastructure at latencies low enough to support collision-avoidance and eventually fully autonomous driving. In agriculture, 5G-connected soil, weather, and crop sensors, together with drone-based imagery, support precision-farming decisions at a density and responsiveness that earlier cellular generations could not sustain. Smart cities draw on all three service pillars simultaneously: eMBB for public Wi-Fi and video surveillance, URLLC for traffic-signal coordination and emergency response, and mMTC for the dense sensor networks that monitor air quality, water systems, and energy grids.

Beyond these vertical industries, 5G is also an enabler of new consumer and enterprise experiences. Cloud gaming and immersive virtual and augmented reality applications, which require both high throughput and very low motion-to-photon latency, become commercially viable over 5G in ways that were impractical over 4G. Enterprises are also beginning to build private 5G networks — dedicated, often on-premises deployments — to gain the reliability and security benefits of network slicing without depending on public mobile operators, particularly in manufacturing and logistics settings where data sovereignty and deterministic performance are paramount. Table 2 summarizes representative application domains, the 5G

service pillar each primarily depends on, and the qualitative benefit each derives from the technology.

Table 2: Representative 5G applications by sector

Sector	Representative Application	Primary 5G Service Pillar	Key Benefit
Healthcare	Remote diagnostics, wearable monitoring, remote-assisted surgery	URLLC	Reduced preventable hospital interventions; real-time vitals monitoring
Manufacturing	Connected robots, automated guided vehicles, condition monitoring	URLLC / mMTC	Real-time coordination; predictive maintenance; reduced downtime
Transportation	Vehicle-to-Everything (V2X) communication, traffic management	URLLC	Collision avoidance; foundation for autonomous driving
Agriculture	Soil/weather/crop sensors, drone-based imagery	mMTC / eMBB	Precision-farming decisions at high sensor density
Smart Cities	Traffic signals, surveillance, utility & environmental sensors	eMBB / URLLC / mMTC	Coordinated, city-scale automation and monitoring
Consumer/Enterprise Media	Cloud gaming, virtual and augmented reality	eMBB	High-throughput, low motion-to-photon-latency immersive experiences
Enterprise/Industry 4.0	Private 5G networks with network slicing	All three pillars	Deterministic performance and data sovereignty on dedicated infrastructure

5. 5. Economic Impact on Global Connectivity

The economic case for 5G rests on efficiency gains, new revenue-generating services, and productivity improvements across sectors that depend on real-time data and automation. Cross-industry analyses estimate that 5G-enabled efficiency and new applications could add between roughly US\$500 billion and US\$1.3 trillion to global GDP by 2030, with the exact figure depending on the scope of use cases and assumptions modeled by each analysis. Figure 3 presents one widely cited sectoral breakdown, in which healthcare and social care are projected to capture the single largest share of this contribution, reflecting the scale of efficiency gains available from remote monitoring, smart diagnostics, and reduced preventable hospital admissions, followed by smart-utilities management, consumer and media applications, and industrial manufacturing. Regionally, large manufacturing-based economies such as the United States, China, and Japan are projected to see the greatest absolute GDP uplift, given the size of their existing industrial bases and their relatively rapid 5G infrastructure rollout, while regions with strong agricultural or utilities sectors — India is one frequently cited example — are projected to see disproportionate gains in those specific verticals.

These projections should be read as directional rather than precise, since they depend on assumptions about the pace of 5G adoption, regulatory approval of applications such as autonomous vehicles and beyond-visual-line-of-sight drones, and the rate at which enterprises invest in the complementary digital infrastructure — edge computing, IoT device fleets, and data analytics platforms — needed to capture the value

that raw connectivity alone does not deliver. Nonetheless, the consistent finding across independent analyses that healthcare, manufacturing, and utilities will be the largest beneficiaries provides a useful prioritization signal for policymakers and investors deciding where to focus limited 5G deployment and spectrum-allocation resources first.

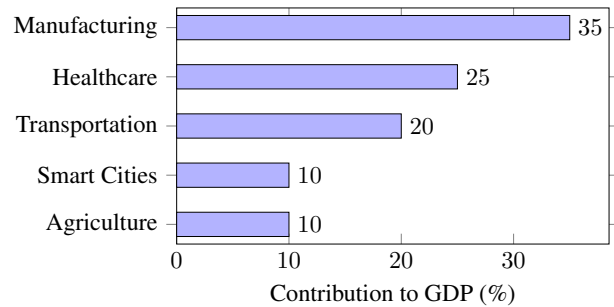


Figure 3: Projected sectoral contribution of 5G to global GDP by 2030

6. 6. Challenges and Limitations

Realizing 5G's connectivity potential at global scale faces three interlinked categories of challenge. The first is infrastructure investment: achieving mmWave-grade throughput and the ultra-low latency required for URLLC applications requires a much denser deployment of small cells and fiber backhaul than 4G, since mmWave signals have limited range and

are easily attenuated by buildings, foliage, and even heavy rain. This raises capital expenditure substantially, particularly in rural and low-income regions where the revenue per subscriber may not justify dense infrastructure investment on purely commercial terms, creating a risk that 5G's benefits accrue disproportionately to already well-connected urban and high-income areas unless complemented by public investment or hybrid architectures that combine 5G with lower-cost LP-WAN coverage for sparse areas.

The second challenge is security. The same software-defined, virtualized architecture that gives 5G its flexibility also expands the attack surface relative to earlier, more hardware-centric network generations: network slices must be securely isolated from one another, the growing population of often resource-constrained IoT endpoints frequently lacks the computational headroom for conventional enterprise-grade security software, and the sheer number of connected devices — projected in the tens of billions — multiplies the number of potential entry points for unauthorized access, denial-of-service attacks, and data exfiltration. Addressing this requires purpose-built, lightweight security frameworks for constrained edge devices, robust device-authentication protocols, and increasing use of AI-based anomaly detection to identify compromised devices or abnormal traffic patterns in near real time.

The third challenge is regulatory and spectrum-related. Because usable 5G spectrum bands differ by country, and because applications such as autonomous vehicles, beyond-visual-line-of-sight drones, and remote surgery raise safety, liability, and data-protection questions that go beyond pure connectivity, the pace of regulatory approval — not the underlying technology — is frequently the binding constraint on how quickly certain high-value use cases can be deployed. Cross-border interoperability is a further complication for multinational enterprises and international logistics, since inconsistent spectrum allocation and differing national security requirements can fragment what is, in principle, intended to be a globally standardized technology.

7. 7. Future Scope

Looking beyond current deployments, several developments are likely to shape the next phase of 5G's impact on global connectivity. Standalone 5G core deployments — which fully replace 4G core infrastructure rather than operating in a non-standalone mode that still depends on it — are expected to unlock the full latency and network-slicing benefits of the standard as operators complete their infrastructure transitions. Integration with artificial intelligence for autonomous network management, including self-optimizing radio resource allocation and AI-based security monitoring, is an active area of both research and commercial deployment, aiming to reduce the operational cost of managing increasingly complex, densely sliced networks. Research and early standardization work on 6G is already underway, targeting further reductions in la-

tency, higher device density, and native integration of satellite and terrestrial networks to close remaining rural and maritime connectivity gaps that even mature 5G deployments are unlikely to fully address on their own. Finally, as private 5G networks become more accessible to mid-sized enterprises, the economic benefits currently concentrated among large manufacturers and telecom-adjacent industries are likely to broaden, provided that the infrastructure-investment and security challenges discussed above are addressed through a combination of continued cost reduction, supportive regulation, and public-private investment in underserved regions.

8. 8. Conclusion

5G represents a structural rather than incremental advance in mobile connectivity, combining enhanced mobile broadband, ultra-reliable low-latency communication, and massive machine-type communication within a single, software-defined, sliceable network architecture. This combination is what allows 5G to simultaneously serve consumer video streaming, safety-critical industrial and vehicular automation, and dense IoT sensor networks — use cases that earlier mobile generations could not support concurrently. Cross-sector evidence indicates that healthcare, manufacturing, and utilities are likely to capture the largest share of the trillion-dollar-scale global economic contribution projected for 5G by 2030, driven respectively by remote diagnostics and monitoring, industrial automation, and smart-grid efficiency. Realizing this potential at global scale, however, depends on resolving substantial infrastructure-investment, cybersecurity, and regulatory challenges, particularly to avoid a widening connectivity gap between well-capitalized urban markets and rural or lower-income regions. As standalone 5G core deployments mature and research toward 6G begins in earnest, sustained attention to equitable infrastructure investment and security-by-design will determine whether 5G's promise of redefining global connectivity is realized broadly rather than only for the markets best positioned to capture it first.

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