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Security Risks in 5G

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Abstract - This paper presents a comprehensive review of security vulnerabilities in fifth-generation (5G) wireless networks. It investigates emerging threats across the core network, protocol layers, and software-defined infrastructures, emphasizing risks introduced by network slicing, open APIs, and virtualization. The methodology involves comparative analysis of recent technical literature and classification of threats such as denial-of-service attacks, weak authentication mechanisms, and endpoint vulnerabilities. The study evaluates current mitigation strategies including encryption, slice isolation, and secure device authentication, identifying their limitations in real-world deployment. Key findings highlight persistent gaps in standard implementation, especially in maintaining confidentiality, integrity, and availability in hyperconnected environments. The paper concludes with recommendations for future research, including AI-based threat detection, post-quantum cryptographic solutions, and adoption of zero-trust security frameworks. The insights aim to assist researchers, network operators, and policymakers in strengthening the resilience of 5G infrastructures against evolving cyber threats.

Key Words: 5G,DDos Attacks,IOT Vulnerabilities,Network Security,Network Slicing

1. INTRODUCTION

The global rollout of 5G networks represents not only an evolution in mobile telecommunications but also the foundation for a fully connected digital future. With ultra-low latency, high-speed connectivity, and the capacity to support billions of devices, 5G enables transformative applications in healthcare, autonomous systems, industrial automation, and smart infrastructure. However, this advancement significantly broadens the attack surface and introduces complex cybersecurity challenges.

Unlike previous generations, 5G is more than a bandwidth upgrade—it redefines mobile network architecture by incorporating Software Defined Networking (SDN), Network Function Virtualization (NFV), and service-based models using open APIs and HTTP-based interfaces. These enhancements improve flexibility and scalability but also create new vectors for attack.

This paper explores the security implications of 5G across multiple architectural layers. The objective is to uncover critical vulnerabilities, categorize various types of attacks across both protocol and system layers, assess the shortcomings of existing security models, and propose future research pathways that contribute to building a more secure and robust 5G network infrastructure.

2. Review Methodology

This study adopts a structured integrative review methodology, focusing on academic and institutional research published between 2019 and 2024. Nine peer-reviewed articles were selected based on their relevance to the cybersecurity landscape of 5G networks. The selection criteria focused on cybersecurity elements essential to 5G architecture, aiming to achieve thorough representation across all OSI layers—from the physical layer up to the application layer.

Each study was assessed for technical depth, methodological rigor, and the diversity of threat vectors addressed. Priority was given to literature discussing a broad spectrum of attack surfaces, including physical infrastructure vulnerabilities, virtualized network function (VNF) threats, signaling protocol exploits, and software-based intrusions.

Special attention was paid to identifying sophisticated threats such as those posed by nation-state actors and advanced persistent threats (APTs). The selected papers were thematically categorized into security domains, including supply chain integrity, user privacy, edge computing vulnerabilities, and inter-slice isolation risks. A qualitative synthesis was employed to extract recurring patterns, highlight differences in implementation practices, and identify common mitigation strategies. Real-world case studies, attack simulations, and architectural insights were also examined to inform the empirical understanding of 5G vulnerabilities.

This thematic synthesis guided the structure of the main body, which is organized into targeted discussion clusters covering device-level security, network slicing threats, and privacy-related concerns.

This review draws on scholarly articles, technical whitepapers, and industry publications to provide a comprehensive analysis of cloud computing security. The literature was selected primarily from IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar. The search was limited to studies published between 2010 and 2025, using keywords such as 'cloud computing security', 'zero trust architecture', 'confidential computing', and 'cloud threats'. Inclusion criteria focused on peer-reviewed papers, industry standards, and authoritative reports relevant to technical or strategic aspects of cloud security. Studies that lacked substantial technical detail or empirical evidence were excluded. Thematic categorization was used to structure the review around key areas such as threats, mitigation strategies, and emerging technologies.

3. Main Body

a) The Evolving 5G Landscape and Its Security Paradigm

5G networks are not merely an upgrade to 4G technology; rather, they represent a fundamental transformation in mobile network architecture and service delivery. Central to this shift is the adoption of a **Service-Based Architecture (SBA),** which replaces the monolithic, tightly integrated structures of previous generations with **modular, software-defined components** that interact through standardized APIs [1], [2].

Although this shift in architecture offers major advantages like enhanced scalability, flexibility, and the ability to support emerging applications such as Ultra-Reliable Low-Latency Communication (URLLC) and Massive Machine-Type Communication (mMTC), it also brings forth intricate security concerns.The reliance on HTTP/2, RESTful APIs, and open

interfaces increases the attack surface. Additionally, the integration of Virtualized Network Functions (VNFs), containerized microservices, and extensive involvement of third-party vendors and IoT ecosystems poses new risks that traditional security models were not designed to handle [4], [6].

5G's use of Network Exposure Functions (NEF) and Service Capability Exposure Functions (SCEF) raises the risk of unauthorized access, traffic manipulation, and session hijacking if access controls and authentication mechanisms are not properly enforced [1]. Furthermore, the proliferation of unsecured IoT devices—coupled with 5G's ultra-dense connectivity—creates a vast and vulnerable threat surface. A single compromised endpoint can trigger large-scale botnet-driven Distributed Denial of Service (DDoS) attacks across multiple slices due to shared infrastructure [4].

These architectural changes necessitate a shift from legacy security paradigms to more adaptive approaches, including **zero-trust architecture, dynamic threat detection, and slice-aware policies** [5], [6].

b) Security Vulnerabilities by OSI Layer

A comprehensive evaluation of 5G vulnerabilities can be structured through the lens of the OSI model [5], [6]. At the **Application Layer (Layer 7),** prominent threats include malicious mobile applications, rogue service requests, and inadequate identity and access management mechanisms. The integration of advanced technologies such as blockchain and artificial intelligence introduces additional risks, including transaction malleability and susceptibility to adversarial inputs [7]. Recommended countermeasures at this layer include **API authentication, tokenization, deep packet inspection,** and **behavioral analysis** [6].

The **Session and Presentation Layers (Layers 5 and 6),** although traditionally underemphasized, are vital in 5G for ensuring secure communication sessions and proper data encryption/decryption. Vulnerabilities such as **weak session handling, insecure cipher negotiations**, and **fallback to legacy protocols** are notable concerns. Mitigation strategies include the adoption of **TLS 1.3, secure session token management,** and **protocol hardening** [5].

At the **Transport Layer (Layer 4),** which is governed by TCP and UDP, common threats include **SYN flood, fragmentation attacks,** and **lack of encryption over UDP**, exposing sensitive metadata. Suggested defenses include **rate limiting, robust session control,** and **transport-layer encryption** mechanisms [4].

Layer 3, also known as the Network Layer, continues to face threats such as IP spoofing, manipulation of routing paths, and attacks exploiting the GPRS Tunneling Protocol (GTP), especially in older core network infrastructures.Despite improvements brought by **software-defined** enforcing **inter-slice isolation** and achieving **slice-specific routing integrity** [6], [9].

At the lower **Data Link and Physical Layers (Layers 2 and 1)**, risks such as **eavesdropping, jamming, and physical tampering** are especially prevalent in **dense small-cell deployments**. The use of **millimeter wave (mmWave)** frequencies introduces propagation-related complexities and new attack surfaces. Security mechanisms here include **physical-layer encryption**, **beamforming**, **tamper-resistant hardware**, and **real-time base station monitoring** [4], [8].

Since vulnerabilities span across all OSI layers, a **layered defense strategy** is essential. Each layer must implement targeted security protocols to reduce lateral attack movement and prevent systemic compromise [5], [6].

c) Protocol-Based Attacks in the 5G Core Network

The core architecture of 5G is built upon contemporary communication technologies like HTTP/2, RESTful APIs, and JSON, representing a major shift away from traditional protocols such as SS7 and Diameter.While these technologies enhance interoperability and programmability, they also expose the network to **well-known web-based threats** [1], [2].

Key vulnerabilities arise from improperly secured interfaces, enabling attacks such as **API injection, session hijacking, cross-site scripting (XSS)**, and **man-in-the-middle (MitM)** exploits. Functions like the **Network Exposure Function (NEF)** and **Service Capability Exposure Function (SCEF),** which expose core network capabilities to third-party applications, are especially susceptible. Exploiting these components may allow adversaries to manipulate **authentication flows, quality-of-service (QoS) parameters,** or even influence **user mobility** across slices [1], [4].

In addition, the architectural transformation involving **GTP-to-HTTP conversions**—used for separating user and control planes—remains inconsistently standardized across vendors. This inconsistency can be exploited to bypass encryption or authentication mechanisms, enabling **replay attacks, rogue service provisioning,** and **data leakage** [1], [5].

Although specifications like **3GPP TS 33.501** recommend securing the interconnect through solutions such as the **Security Edge Protection Proxy (SEPP)** and **IMSI encryption**, real-world implementation varies between network operators and vendors. This fragmented adoption increases the **supply chain risk,** particularly in multi-vendor environments [6].

Furthermore, **user plane protocols** often lack sufficient protection. Malicious IoT traffic targeting the user plane can evade detection in **virtualized, software-defined networks,** especially when **Multi-access Edge Computing (MEC)** nodes or virtual slices with weak security controls are compromised. In such environments, even strong encryption does not prevent **data interception or redirection** [1], [7].

d) Risk associated with Network Slicing, Virtualization, and Supply Chain:

Network slicing is one of the most transformative innovations in 5G, allowing a single physical infrastructure to be divided into multiple logical segments or "slices," each optimized for specific applications or user groups. Despite its advantages, this architectural shift introduces significant **security risks** [3], [1].

The **increased configuration complexity** of slicing frameworks elevates the likelihood of **human error, misconfigurations, and policy enforcement gaps.** For example, a slice configured for mission-critical services—such as **industrial automation** or **smart grids**—may unintentionally share vulnerabilities with slices handling **less secure consumer traffic,** especially when resources like physical hardware, hypervisors, or orchestration layers are shared [3], [6].

When **slice isolation** mechanisms fail—whether due to **API exploitation, insecure virtual machines, or compromised shared resources**—an attacker can potentially execute **lateral attacks,** moving across slices undetected. The use of **Software-Defined Networking (SDN)** and **Network Function Virtualization (NFV)** further complicates the security posture by dynamically reallocating workloads, which makes it difficult to monitor and secure each slice independently [1], [7].

Moreover, the **5G supply chain** introduces additional risks, as networks often incorporate **hardware and software components from diverse global vendors,** each with distinct security policies, update cadences, and trust levels. A vulnerability in any single component—such as a **baseband chipset, virtual switch**, or **MEC (Multi-access Edge Computing) node**—can jeopardize the integrity of the entire system [1], [6].

Many network slices also share critical underlying infrastructure components like **hypervisors, caching layers**, and **management interfaces**, potentially **nullifying encryption boundaries** or **quality-of-service (QoS) guarantees**. These shared dependencies increase the risk of **cascading failures,** where a breach in one area compromises multiple slices, threatening the security and reliability of the entire slicing mechanism [6], [8].

e) IoT Security and Device Authentication Challenges

The proliferation of Internet of Things (IoT) devices in 5G networks—often exceeding one million devices per square kilometer—introduces significant security vulnerabilities across both consumer and industrial applications [4]. Many of these devices, ranging from smart home sensors to mission-critical medical equipment, possess limited computational power and lack essential security features such as firewalls, certificate-based authentication, and strong encryption mechanisms [8].

This constrained architecture makes IoT devices prime targets for a wide array of cyber threats, including distributed denial-of-service (DDoS) attacks, identity spoofing, and firmware manipulation. A single compromised device can serve as a launchpad for reflection or amplification attacks or become a pivot point to compromise Multi-access Edge Computing (MEC) nodes—critical components responsible for local traffic routing and data processing [9].

The current SIM-based Public Key Infrastructure (PKI), though effective in traditional mobile ecosystems, becomes cumbersome when scaled to accommodate millions of devices using eSIMs or embedded authentication credentials [6]. The compromise of a few credentials can lead to mass impersonation attacks or unauthorized network access, especially in environments with weak session token management.

While unified authentication mechanisms—such as the Security Anchor Function (SEAF)—are outlined in 3GPP standards to mitigate these risks, their effectiveness depends heavily on proper vendor implementation and configuration [6]. Additionally, many IoT devices, particularly in industrial deployments, do not receive regular firmware updates due to operational constraints. This opens the door to long-dwell attacks, where adversaries maintain persistent access without detection over extended periods [9].

f) Confidentiality, Integrity, and Availability (CIA) Threats in 5G

The three foundational pillars of cybersecurity—**Confidentiality, Integrity, and Availability (CIA)**—provide a critical framework for assessing the resilience of 5G systems. While the 5G architecture introduces enhancements intended to strengthen these dimensions.

- **Confidentiality**

  The confidentiality of 5G communications is increasingly at risk due to the use of open protocols and the exponential rise in connected endpoints. The reliance on HTTP/2, REST APIs, and service exposure functions like NEF and SCEF in the 5G Core (5GC) can lead to data interception, especially when APIs are misconfigured or insufficiently protected [1].

  Although 5G mandates IMSI encryption to obscure subscriber identities over the air interface, this protection does not comprehensively extend to device-to-device (D2D) communications or MEC-level exchanges, where non-3GPP access points may bypass authentication controls [4].The lack of consistent end-to-end encryption—particularly between edge nodes and centralized cloud components—further exacerbates the risk of sensitive data leakage. Moreover, the convergence of diverse data types (e.g., personal, medical, and industrial) over shared infrastructure raises the potential impact of any confidentiality breach [6].

- **Integrity**

  Threats to data integrity in 5G stem from the possibility of unauthorized modifications to control-plane signaling and user-plane data flows. Virtualized Network Functions (VNFs), if compromised, could be used to inject false routing information, alter service quality parameters, or manipulate billing data [9].

  Due to the software-defined nature of network management in 5G—especially through SDN and NFV—attackers who gain access to orchestration platforms may tamper with slice configurations or memory caches shared among tenants. Improper slice isolation can lead to lateral movement between slices, allowing one compromised domain to influence others [6].

- **Availability**

  Availability is perhaps the most threatened aspect of 5G, given its mission-critical applications and ultra-dense device ecosystems. The widespread deployment of small cells, CPEs, and MEC nodes expands the attack surface for **Distributed Denial of Service (DDoS)** attacks [1]. Massive Machine-Type Communications (mMTC), while enabling scalability, also increases the risk of large-scale botnet activity if IoT endpoints are hijacked.

  Individual network slices can become targets for DDoS attacks, which may lead to the disruption of critical services such as emergency communications or industrial automation—particularly when the isolation between slices is not strongly maintained.Furthermore, the reliability of patch distribution and over-the-air updates is vital to maintaining availability. Disruption of update channels, whether via jamming or protocol exploitation, can render large segments of the network inoperable [9].

g) Security Benefits of 5G Over 4G – And Their Limitations

While 5G faces numerous security challenges, it also introduces important enhancements compared to 4G that can significantly strengthen mobile network security. However, these benefits depend heavily on consistent, end-to-end implementation by network operators and equipment manufacturers [1], [3].

Key Advantages:

- **Improved Authentication**
  5G employs the 5G-AKA protocol, which provides mutual authentication between devices and the network, offering stronger protection than 4G's version. It also enables extended protection of subscriber identity (IMSI) by encrypting it at the radio layer, reducing the risk of tracking and interception [1], [4].

- **Enhanced Core Security with SEPP**
  The deployment of the Security Edge Protection Proxy (SEPP) strengthens communication security between various Public Land Mobile Networks (PLMNs) by defending against threats such as signaling spoofing and manipulation in roaming environments. This marks a notable improvement over the security mechanisms used in 4G roaming scenarios [1], [3].

- **Distributed Core and MEC Security**
  The adoption of cloud-native core architectures and Multi-access Edge Computing (MEC) distributes security functions closer to the network edge, reducing single points of failure and enabling faster detection and mitigation of threats [6].

- **Network Slicing Isolation**
  5G supports granular network slicing, allowing operators to define unique security policies per slice, thus isolating critical services from less secure or public-facing slices. This capability facilitates tailored security controls based on the specific risk profiles of different applications [1], [3].

- **Support for PKI and Certificate-Based Access**
  Unlike 4G, 5G broadens the adoption of Public Key Infrastructure (PKI) for device authentication, enabling secure device-to-device communication outside the core network path, enhancing overall trustworthiness of IoT and other endpoints [6].

Limitations:

Despite these advantages, several practical limitations can undermine 5G's security improvements:

- **Partial Deployment**
  A significant number of network providers continue to operate 5G using the Non-Standalone (NSA) architecture, which integrates the 5G radio access network (RAN) with the existing 4G core. This approach carries forward certain legacy security weaknesses and restricts the full range of security enhancements offered by a complete 5G core deployment [3].

- **Operator Discretion**
  Due to cost pressures, operational complexity, or insufficient awareness, some operators may delay or omit security feature deployment, leaving parts of the network exposed to attacks [4].

- **Lack of Cross-Vendor Enforcement**
  Vendors may interpret 5G security standards differently, leading to inconsistent SEPP implementations and interoperability challenges that can weaken roaming security [1].

- **IoT Constraints**
  Although 5G supports stronger authentication, many low-cost IoT devices still lack the hardware capability to implement robust encryption or authentication protocols, presenting persistent vulnerabilities at the network edge [6].

h) Gaps in Current 5G Security Standards and Governance

While organizations such as 3GPP, ITU, and ETSI have established robust security standards for 5G, significant gaps persist in both the scope and enforcement of these standards.

- **FragmentedImplementation**
  The absence of globally harmonized enforcement leads to wide variability in 5G security across countries, operators, and vendors. Differing governmental policies in the U.S., U.K., and EU regarding trusted vendors, supply chain transparency, and cybersecurity audits result in uneven compliance levels. This fragmented approach makes it more challenging to achieve secure and seamless 5G interoperability across international networks [7].

- **Incomplete Protection in the User Plan**
  Most 5G security efforts focus on the control plane—such as signaling encryption and authentication frameworks—while user plane traffic (the actual data payload) often remains inadequately protected. This exposes the user plane to traffic analysis, spoofing, and lateral movement attacks, particularly in virtualized network environments [1], [6].

- **Inadequate Threat Intelligence and Detection**
  Current standards do not mandate robust real-time threat detection using AI and machine learning. As 5G scales to millions of endpoints with decentralized traffic flows, traditional perimeter-based defenses become insufficient. There is a critical need for distributed threat intelligence capable of detecting and isolating anomalies across network slices and administrative domains in real time [4], [9].

- **Lack of Accountability for Third-Party Integrators**
  With the expansion of open APIs and third-party integrations—especially in sensitive sectors like industrial automation and healthcare—security responsibilities become diffuse. Existing frameworks inadequately assign liability among providers, integrators, and application developers, complicating responses to breaches or denial-of-service incidents originating from third-party vulnerabilities [2], [7].

4.Discussion and Research Gaps

The analysis presented throughout this study underscores both the technological advancement and the inherent fragility of the 5G ecosystem. As evident from the multi-layered vulnerabilities discussed, 5G is not merely a faster network but a completely rearchitected digital infrastructure that incorporates cloud-native technologies, virtualized functions, open interfaces, and hyperconnectivity through IoT devices. This convergence has created a dual-edged paradigm: the power to transform industries, and the parallel risk of systemic compromise if security is not treated as a foundational component [1], [3], [4].

One of the most significant insights from this research is the discrepancy between 5G's security potential and its real-world deployment status. Many of the features touted as security improvements—such as SEPP, network slicing isolation, and AI-enabled threat detection—are either inconsistently implemented or still under development [3], [5]. A disconnect often exists between established security standards and how effectively they are implemented by network operators and equipment vendors.This disparity leaves parts of the 5G infrastructure exposed to legacy vulnerabilities, often aggravated by poorly secured third-party integrations and fragmented governance [7], [9].

Furthermore, the OSI-layered vulnerabilities reveal that while 5G offers more segmented defense opportunities, many layers remain inadequately addressed. For example, the control plane enjoys relatively mature protections, but user plane security is still underdeveloped, and many attacks—particularly those involving IoT DDoS vectors or malicious session manipulation—exploit this imbalance [2], [4], [6]. The reliance on protocols like HTTP/2 and JSON, while efficient, inadvertently transfers the attack surface from proprietary telecom layers to common web technologies well understood by attackers [1], [9].

Another area of concern is the inter-slice security model. Despite the intention of network slicing to deliver logical separation between services, in practice, shared hypervisors, APIs, and misconfigurations can allow for lateral movement between slices [3], [7]. The lack of tools for formally verifying slice isolation policies further complicates the ability to ensure service boundaries are respected and secure [5].

Device-level threats are also exacerbated by IoT proliferation, where billions of endpoints—many with minimal security postures—act as soft entry points into highly dynamic network environments. The traditional PKI model, while still in use, is not equipped to scale or adapt to IoT's demands. Compromised keys or eSIM mismanagement can have cascading effects, potentially enabling impersonation or persistent unauthorized access across slices or domains [4], [8].

Finally, governance and standardization present critical gaps. There is currently no globally harmonized framework for 5G cybersecurity oversight. Variability in vendor practices, national regulations, and incident disclosure requirements complicates coordinated responses to threats that often transcend geographic boundaries. This fragmentation poses risks for international roaming, supply chain assurance, and trust in transnational data handling [3], [7].

In summary, the discussion reveals that while 5G is built on a more secure design philosophy than its predecessors, its implementation, operation, and regulation remain areas of active concern. Security cannot be an afterthought or layered on once services are deployed—it must be engineered into every component and lifecycle phase. Addressing the research gaps identified here is crucial for realizing the full potential of 5G without compromising its integrity or safety [1], [5], [9].

5.Future Research Directions

The rapid evolution and adoption of 5G networks worldwide demand a continuous and forward-looking security strategy. As new technologies, services, and applications emerge, existing security paradigms will be stretched—and potentially broken. This section identifies key future research directions to help ensure the safe deployment and use of 5G and beyond. As 5G networks operate with unprecedented scale and complexity, traditional rule-based threat detection methods are no longer adequate. Future research must focus on developing AI- and ML-based intrusion detection systems (IDS) that can identify anomalies, correlate behaviors across slices, and make real-time decisions to isolate threats [6], [8]. These models must be trained on vast, diverse, and continuously updated datasets—including traffic from IoT devices, MEC services, and mission-critical applications. Furthermore, explainable AI (XAI) approaches are needed to ensure transparency and trust in automated threat mitigation [8].

Zero Trust Architecture (ZTA) has become a critical model in enterprise networks, and its application in 5G is promising. In a Zero Trust Architecture (ZTA), no user, device, or network slice is presumed trustworthy—even if it operates within the internal network boundaries [3], [5]. Future studies should explore how ZTA can be adapted for cross-domain slice access, dynamic access control for MEC and NFV components, decentralized identity verification using blockchain or distributed ledgers, and federated trust models across different 5G operators and vendors.

As quantum computing approaches practical implementation, current encryption protocols (e.g., RSA, ECC) may become obsolete. 5G's long operational life—often exceeding 10–15 years—makes it vulnerable to harvest-now-decrypt-later attacks. There is an urgent need for the 5G security community to adopt and evaluate post-quantum cryptographic algorithms compatible with lightweight devices and virtualized networks [4], [6]. Research must also examine key distribution schemes that do not rely on centralized authorities, enabling secure communications in decentralized environments.

Although slicing is intended to isolate services, real-world implementations often expose inter-slice vulnerabilities due to shared hypervisors, SDN controllers, or physical resources [2], [7]. Future research should focus on creating tools and frameworks that can rigorously validate slice isolation, perform forensic investigations in cases of cross-slice breaches, and monitor SDN traffic and resource distribution in real time.

Finally, the current fragmented governance landscape is a major security risk. Research must evaluate the feasibility of a global 5G cybersecurity treaty or oversight framework, with standardized certification, vulnerability disclosure protocols, and incident response coordination across nations [3], [9]. This could be modeled after existing aviation, maritime, or nuclear regulatory bodies. The goal is to build trust without borders, enabling secure international 5G roaming and service integration.

6.Conclusion

5G represents a paradigm shift in telecommunications—not only in terms of performance but also in architecture, deployment, and service diversity. It holds the promise of transforming industries, economies, and daily life through ultra-reliable low-latency communications, massive IoT connectivity, and highly scalable virtualized services.

However, this transformation is shadowed by a complex and growing array of security risks. As this research shows, 5G is vulnerable across all OSI layers—from physical tampering of small cells to core protocol exploits and API attacks. The integration of legacy systems, partial deployments, and a heterogeneous supply chain only increase the risks. Even its strengths, such as network slicing and MEC, open new attack surfaces that require careful design and rigorous testing.

While the 3GPP and other standardization bodies have taken steps to secure 5G, much of the responsibility now lies with network operators, equipment vendors, and application developers.

Future research must address emerging challenges such as real-time AI-based detection, quantum-safe encryption, and zero-trust architectures. In parallel, policymakers must work toward harmonized international standards and regulatory frameworks that support secure, resilient, and trustworthy 5G networks.

The future of 5G is not just faster connections—it is about secure and dependable infrastructure capable of supporting critical sectors and safeguarding global digital ecosystems. Whether that future will be realized safely depends on how seriously we address the risks today.

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