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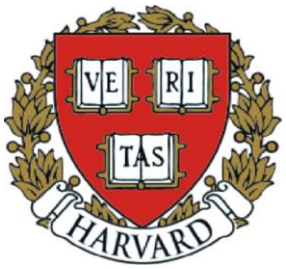


# 5G ENABLED INTERNET OF THINGS: A REVIEW

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## *Abstract*

The integration of 5G wireless technology and the Internet of Things (IoT) has revolutionized connectivity with high speed, ultra-low latency, and expansive device capacity. This paper explores the potential synergy between 5G and IoT, their role in transforming the IoT landscape, and their applications in smart cities, transportation, and health care. The paper emphasizes the importance of seamless connectivity and real-time data exchange across industries and offers an in-depth analysis of the technical features and benefits of 5G technology, such as its ability to transfer large data volumes over shorter distances and

***Keywords:*** 5G, Internet of Things (IoT), Wireless Technologies, Machine Learning (ML).

## INTRODUCTION

The fifth generation of wireless technology (5G), is making a significant impact in the field of connectivity, revolutionizing the way devices communicate with its ultra-fast speeds, ultra-low latency, and the ability to support a massive number of connections simultaneously (Chikezie *et al*., 2022). This technology is rapidly transforming the Internet of Things, enabling devices to communicate more efficiently and seamlessly than earlier technologies.

Additionally, the 5G network has the potential to impact various industries such as healthcare, transportation, and agriculture, making it a key enabler for a more connected world. 5G has the potential to unleash the true benefits of IoT, and it's a game-changer for connected devices

support a massive number of connected devices per square kilometer. However, the paper also raises concerns about the extensive attack surface and diverse nature of interconnected devices, which can lead to significant security risks. The paper proposes leveraging machine learning models for intrusion and anomaly detection to fortify the security landscape within the 5G-IoT ecosystem. The fusion of 5G and IoT technologies provides a connected world while necessitating proactive measures to address security concerns.

like smart devices, sensors, and industrial machinery (Palarimath *et al*., 2023). The promising potential of the synergy between 5G technology and the Internet of Things deserves attention in today's digital landscape. With 5G's lightning-fast speeds, enhanced stability, massive device connectivity, and low latency, it addresses the escalating demand for seamless connectivity and real-time data exchange (Sudheer *et al*., 2023). This is quite a big deal for industries like transportation, healthcare, and generally for smart cities, where rapid response and uninterrupted communication are pivotal. As more IoT devices come up, the power of 5G amplifies their potential, creating an ecosystem that drives a more connected future.

**Evolution of Wireless Connectivity**

IoT is a network of physical devices, including vehicles, home appliances, and more that are equipped with electronics, software, sensors, and connectivity capabilities. These devices can communicate with each other and exchange data, making them "smart" and more efficient. The goal is to enable objects to interact with each other and their environment in real-time (Lin and Xiang, 2023). The evolution of wireless technologies has played a significant role in the development of IoT.

Wireless technologies have evolved from the first-generation (1G) analog cellular networks to the fifth-generation (5G) networks that are currently being deployed. The first-generation analog cellular networks were introduced in the 1980s and were followed by second-generation (2G) digital cellular networks in the 1990s. The 2G networks were replaced by third-generation (3G) networks in the early 2000s, which provided faster data transfer rates and enabled the use of smartphones. Fourth-generation (4G) networks were introduced in the late 2000s and provided even faster data transfer rates, which enabled the development of IoT devices (Kadus and Wabale, 2023).

The evolution of wireless technologies has enabled the development of IoT devices that can communicate with each other and with the internet. These devices use a

variety of wireless technologies, including Wi-Fi, Bluetooth, Zigbee, Z-Wave, and cellular networks, to connect to the internet and exchange data. Wi-Fi is a popular wireless technology that is used in many IoT devices, including smart home devices, security cameras, and smart speakers (Kadus and Wabale, 2023). The development of wireless local area networking (WLAN) by IEEE 802.11 standard, commonly known as Wi-Fi, has transformed daily life, connecting billions of IoT devices, such as smartphones, tablets, computers, TVs, and other consumer devices, to the internet to enable connections to reach everyone, everywhere. With more than a billion access points around the world, Wi-Fi has become an integral part of our daily lives. (Khanh *et al*., 2022).

The evolution of wireless technologies has also resulted in the development of 5G networks, which are currently being deployed. 5G networks provide faster data transfer rates, lower latency, and higher capacity than 4G networks. This will enable the development of new IoT applications and services (Khanh *et al*., 2022).

**Challenges in Modern Communication**

As the number of connected devices continues to grow, the demand for faster and more reliable network connectivity has increased substantially. Nowadays, devices are becoming more powerful and demanding immediate response (Haring *et al*., 2021). It's safe to say that the world of devices has become more competitive. In a densely populated 2.4 GHz Wi-Fi network, multiple users may experience slow internet connection due to the limited number of available channels. This can lead to network unreliability and poor performance. The implementation of dual-band Wi-Fi routers provides a solution to this challenge. This technology enables devices to connect to different channels, resulting in more stable and reliable internet connection, faster communication, and improved performance.

However, let's put aside WiFi, Ethernet, and other stationary connections for now. Let us highlight a specific group of network users who don't heavily depend on mobile networks, or don't rely on them at all. I am referring to devices that operate on Low-power Wide-area networks (LPWANs), connecting to either mobile or wired infrastructures. Technologies like Long Range Wide Area Network (LoRaWAN) and SigFox, are highly recommended for IoT, especially for energy-efficient autonomous devices and areas with limited mobile network coverage (Garlisi *et al*., 2023). While these networks offer numerous advantages and are widely used in many IoT solutions, they also come with various limitations.

Typically, these networks are well-suited for specific devices that don't need constant connection and immediate access to the cloud. Such networks may not guarantee rapid device responses or real-time device status updates. Additionally, only a few devices can connect to a single base station at a time. Nevertheless, LPWANs remain quite effective in numerous IoT scenarios where rapid

interactions aren't critical, and operating with minimal data portions is sufficient.

Several studies have compared the performance of LPWAN technologies, particularly LoRaWAN and Sigfox, in various scenarios. Garlisi *et al*. (2023) and Perez *et al*. (2022) found that LoRaWAN outperformed Sigfox in terms of coverage and packet delivery rate, with Sigfox showing better energy efficiency. Mekki *et al*. (2019) further emphasized the advantages of both LoRaWAN and Sigfox in terms of battery lifetime, capacity, and cost, while Osman and Abbas, (2022) highlighted Sigfox's lower collision and packet error rates. These findings collectively suggest that both LoRaWAN and Sigfox have their own strengths and are suitable for different IoT applications, with LoRaWAN excelling in coverage and Sigfox in energy efficiency and network performance.

**Technical Advantages of 5G Technology**

To begin with, 5G has the capability to transfer larger data volumes over shorter distances compared to 4G LTE, resulting in substantially faster data transfer speeds (Chikezie *et al*., 2022). Another significant advantage of the 5G network is its enhanced stability, especially for moving clients. Even at speeds of up to 500 km/h, 5G clients can maintain a stable connection, surpassing LTE's limitation of only 120 km/h (Pan *et al*., 2022).

Furthermore, 5G utilizes new frequencies, ranging from 3.4 to 3.8 GHz, allowing it to serve a large number of clients simultaneously. As a result, network clients do not experience significant waiting times to establish connections (Imam-Fulani *et al*., 2023).

An essential aspect of IoT applications is the extremely low latency of 5G, compared to 4G. In an ideal 5G network, latency is less than 10-20 ms, while LTE presently offers a minimum latency of 20 ms (Attaran, 2023).

5G is designed to support a massive number of connected devices per square kilometer, making it ideal for Internet of Things (IoT) deployments where a multitude of sensors and devices need to communicate concurrently.

Additionally, 5G boasts impressive energy efficiency. It allows devices to switch into low energy consumption mode when a mobile connection is unnecessary, resulting in extended battery life for the same device.

**5G-IoT Architecture**

5G IoT Architecture is a robust framework for deploying IoT applications leveraging the 5G communication technology. It provides an end-to-end approach for connecting IoT devices, enabling remote monitoring, control, and data transmission with ultra-high-speed connectivity, low latency, and high reliability.

The architecture of 5G-IoT comprises of several layers, including the device layer, network layer, service layer, and application layer. Each layer has its set of functions and responsibilities, and together, they enable the seamless integration of IoT devices into 5G networks (Kar *et al*., 2021).

**The Application Layer**

The application layer is the topmost layer of the 5G-IoT architecture, providing an interface between the IoT infrastructure and end-users (Jienan *et al.*, 2021). It includes applications designed for specific industries and use cases, such as agriculture, manufacturing, healthcare, and transportation. The application layer uses various IoT platforms, cloud services, and analytics tools to process and analyze data from the physical world and provide real-time insights for better decision-making.

**The Device Layer**

The device layer consists of various IoT devices such as sensors, actuators, controllers, and gateways, which collect and process data from the physical world (Balali *et al*., 2020; Bayılmış *et al*., 2022). These devices are equipped with a variety of networking technologies such as Wi-Fi, Bluetooth, and cellular, and they communicate with each other through gateways, which act as mediators between the device and network layers.

**The Network Layer**

The network layer provides connectivity between IoT devices and the 5G network. It includes a variety of components such as base stations, gateways, IoT platforms, and cloud services, which facilitate communication between devices and provide them with access to the internet (Thilakarathne *et al*., 2022). The network layer also supports various 5G technologies such as ultra-reliable low-latency communication (URLLC), massive machine-type communication (mMTC), and enhanced mobile broadband (eMBB) for different IoT applications.

**The Service Layer**

The service layer provides advanced IoT services and applications, including data analytics, real-time monitoring, and remote control (Shah *et al*., 2020). This layer leverages the capabilities of 5G networks, such as high bandwidth, low latency, and massive connectivity, to deliver innovative IoT solutions.

**Revolutionary Applications of IoT Empowered by 5G technology**

The fusion of 5G technology and the Internet of Things (IoT) has sparked a revolution in various industries, unlocking a realm of innovative applications and possibilities.

**i. Smart Cities**

The integration of 5G networks with IoT devices is reshaping urban landscapes by enabling interconnected systems that enhance city living. Through a web of sensors and devices, traffic congestion can be mitigated by dynamically adjusting signal timings based on real-time traffic patterns (Bratulescu *et al*., 2023). Moreover, streetlights equipped with IoT sensors can conserve energy by brightening or dimming based on pedestrian activity. Additionally, advanced surveillance systems, empowered by 5G's high-speed connectivity, bolster public safety through rapid incident detection and response, ensuring a safer urban environment.

**ii. Industrial Automation (Industry 4.0) and Robotics**

In the manufacturing sector, 5G-enabled IoT devices are catalyzing the era of Industry 4.0. These technologies are optimizing operational efficiency by integrating IoT sensors into machinery, allowing real-time data collection and analysis. Predictive maintenance based on these insights prevents equipment failures, minimizing downtime and optimizing production schedules. Xu *et al*. (2019) and Aleksy *et al*. (2019) highlighted the role of 5G in enabling real-time control and monitoring, with Xu *et al*. (2019) emphasizing the architecture's ability to meet ultra-low latency and high-reliability requirements. Slalmi *et al*. (2021) further underscore the transformative impact of 5G on industrial IoT, particularly through its ultra-reliable low-latency communications (uRLLC) service. 5G-powered robotics and automation are transforming production lines, enabling agile and flexible manufacturing processes that swiftly adapt to changing demands. By leveraging IoT and 5G technologies, manufacturers can achieve higher levels of production efficiency (Slalmi *et al*., 2021). Real-time data collection and analysis enable better decision-making, while automation reduces manual labor and human error. This leads to increased productivity, reduced costs, and improved competitiveness.

**iii. Healthcare and Telemedicine**

The fusion of 5G and IoT is revolutionizing healthcare by facilitating remote patient monitoring and telemedicine. Wearable IoT devices equipped with biosensors can continuously monitor an individual's vital signs, sending real-time data to healthcare providers over robust 5G networks. This capability extends medical services beyond hospital walls, ensuring timely interventions and personalized care, particularly in underserved or remote areas where access to healthcare is limited (Georgiou *et al*., 2021).

**iv. Transportation**

5G's low latency and high-speed capabilities are revolutionizing transportation systems. IoT-enabled smart vehicles communicate seamlessly

with infrastructure and other vehicles, fostering an ecosystem where traffic management is dynamic and efficient (Toka *et al.*, 2023). These advancements lay the groundwork for autonomous vehicles, where real-time data exchanges among vehicles and traffic systems ensure safer and more efficient travel. Moreover, public transportation systems are becoming more responsive, providing real-time information to commuters, optimizing routes, and reducing congestion. By enabling connected and autonomous vehicles, IoT and 5G integration can help reduce carbon emissions in the transportation sector (Hakak *et al.*, 2023). Connected vehicles can optimize routes, reduce idling time, and improve fuel efficiency. Autonomous vehicles can also contribute to reduced emissions by minimizing human error and optimizing driving patterns.

**v. Smart Home Security and Automation**

The benefits of 5G technology for smart homes go beyond improving the speed and latency of communication between devices. With its high-speed and low-latency connectivity, smart home devices can be securely integrated and automatically controlled, resulting in faster responses and enhanced security. Wasicek, (2020) highlights the importance of micro-segmentation in ensuring the security of smart home networks that rely on 5G connectivity. This technique provides homeowners with remote access and control over security systems, surveillance cameras, smart locks, and energy management systems. The integration of 5G and IoT in smart homes enables real-time monitoring, automation, and control, resulting in increased convenience, energy efficiency, and a sense of security (Sharma and Goen, 2018). Sharma and Goen, (2018) and Sattaru *et al*. (2023) highlighted the use of IoT in smart home security, with a focus on the use of GPRS for real-time remote alarms, introducing a novel model for monitoring unusual activities.

**vi. Smart Agriculture**

IoT devices empowered by 5G are revolutionizing farming practices, ushering in precision agriculture. These technologies facilitate remote monitoring of soil conditions, crop health, and irrigation systems, allowing farmers to make data-driven decisions in real-time. By leveraging this data, farmers optimize resource usage, reduce water consumption, and increase crop yields, contributing to sustainable and efficient agricultural practices (Sudharson *et al.*, 2023). The integration of IoT and 5G can also play a crucial role in livestock monitoring. Connected sensors can track the health and behavior of animals, providing real-time data to farmers. This enables early detection of diseases, better management of livestock, and improved animal welfare.

**vii. Smart Energy**

5G-enabled IoT devices are revolutionizing energy management and consumption. Smart grids equipped with IoT sensors and meters utilize 5G connectivity to gather real-time data on energy production, distribution, and

consumption patterns (Chen *et al*., 2023). This data allows for more precise energy forecasting, optimization of energy distribution, and load balancing, thereby enhancing the efficiency and reliability of the electrical grid. Moreover, IoT-enabled smart energy systems empower consumers by providing insights into their energy usage, enabling them to make informed decisions to conserve energy and reduce costs.

viii. **Smart Buildings**

The integration of 5G and IoT is transforming conventional buildings into intelligent, responsive spaces known as Smart Buildings. IoT sensors embedded throughout buildings monitor various parameters like occupancy, temperature, lighting, and air quality. With 5G connectivity, these sensors can communicate seamlessly and in real-time, enabling automated responses for energy conservation, comfort optimization, and predictive maintenance. For instance, smart HVAC systems adjust temperature settings based on occupancy data, while lighting systems adjust brightness according to natural light levels, ensuring energy efficiency without compromising comfort. Additionally, predictive maintenance powered by IoT devices and 5G connectivity identifies equipment issues before they escalate, reducing downtime and operational costs (Arora and Yadav, 2022; Narendra Gurjar and Jitendra Dangra, 2022).

ix. **Entertainment and Gaming**

5G's high-speed connectivity and low latency are reshaping the entertainment and gaming industries. Streaming services are delivering high-definition content seamlessly, while gaming experiences are becoming more immersive and responsive, thanks to 5G-powered cloud gaming and augmented reality applications (Hazarika and Rahmati, 2023).

x. **Retail Business**

The integration of 5G and IoT is reshaping the retail landscape, ushering in a new era of personalized and seamless shopping experiences. Retailers leverage IoT sensors embedded in stores and inventory systems, synchronized over 5G networks, to optimize inventory levels and enhance operational efficiency (Zhang, 2021). Additionally, 5G-powered augmented reality (AR) and virtual reality (VR) technologies are transforming the shopping journey, enabling immersive experiences and virtual try-ons, thereby enhancing customer engagement and satisfaction.

## Existing Research Gaps In 5G-Iot Integration

The integration of 5G and IoT has significant potential to usher in a new era of intelligent systems. However, there are several gaps that need to be addressed in order to fully realize the benefits of 5G-IoT integration. Some of the key gaps include:

i. **Interoperability**

One major challenge facing 5G-IoT integration is ensuring interoperability between different systems and devices. Currently, there is no standard framework for communication between different devices and networks, which can lead to security vulnerabilities and compatibility issues (Mir *et al*., 2020)

ii. **Security**

Security is a critical concern in any IoT system, and 5G-IoT is no exception. The increased complexity of 5G networks, combined with the widespread incorporation of IoT devices, creates a complex security landscape that requires careful consideration and ongoing management (Abed and Anupam, 2023).

iii. **Energy Efficiency**

5G-IoT systems are expected to support a variety of edge computing applications, including IoT devices, drones, and autonomous vehicles, among others. However, the need to balance energy efficiency with performance and reliability remains a significant challenge *(Schwab et al*., 2020).

iv. **Spectrum Utilization**

As more IoT devices are integrated into 5G networks, the increased demand for spectrum resources becomes an important consideration. Spectrum utilization will be needed to balance the need for high bandwidth, and low-latency communication while ensuring efficient spectrum usage and minimizing interference (Mallipudi *et al*., 2023).

v. **Network Architecture**

The network architecture of 5G-IoT systems is still evolving, and further research is needed to optimize the design and performance of these systems. This includes exploring alternative network architectures, such as small-cell networks, to enable efficient spectrum usage and support a high density of devices and applications (Kar *et al*., 2021).

## The Security Concerns of IoT and 5G Integration

The integration of IoT (Internet of Things) devices with 5G technology presents a transformative potential across industries, revolutionizing connectivity, and enabling unprecedented advancements. However, this convergence also amplifies significant security concerns that demand meticulous attention and proactive measures to mitigate potential risks (Sicari *et al*., 2020).

One of the foremost apprehensions surrounding IoT and 5G integration is the expanded attack surface it creates. The proliferation of connected devices introduces an intricate web of endpoints susceptible to cyber threats. Given the

vast scale and diverse nature of IoT deployments powered by 5G, ensuring the security of this expansive network becomes increasingly complex (Moudoud *et al*., 2021).

The inherent characteristics of 5G, notably its low latency, high data speeds, and massive device connectivity, exacerbate security vulnerabilities (Alshunaifi *et al*., 2022). These attributes, while instrumental in advancing technological capabilities, pose challenges in safeguarding against potential threats. The rapid and voluminous data exchange between devices within a 5G-enabled ecosystem heightens the risk of cyber intrusions, unauthorized access, and data breaches (Abed and Anupam, 2023).

Moreover, the diverse spectrum of IoT devices, ranging from sensors and actuators to critical infrastructure components, often operate with varying levels of security protocols. This heterogeneity exposes vulnerabilities, as certain devices might lack robust security measures or receive irregular updates, creating potential entry points for malicious actors.

Compounding this concern is the prevalence of outdated firmware and insufficient encryption mechanisms within IoT devices. Inadequacies in device security measures can serve as entryways for cyber-attacks, leading to data manipulation, service disruption, or exploitation of sensitive information (Chauhan and Varma, 2020).

Furthermore, the distributed and decentralized nature of IoT ecosystems, coupled with the dynamic nature of 5G networks, poses challenges in monitoring and managing security threats effectively. Traditional security approaches may prove inadequate in addressing the evolving landscape of sophisticated cyber threats targeting interconnected devices operating within high-speed, low-latency environments.

In addressing the security challenges inherent in the 5G-IoT ecosystem, leveraging machine learning models for intrusion and anomaly detection emerges as a pivotal strategy. The integration of Machine Learning (ML) models for intrusion and anomaly detection stands as a pivotal solution to address the heightened security concerns in the 5G-IoT ecosystem. By harnessing ML algorithms, this approach offers a proactive means to fortify the security landscape within this interconnected network.

In the context of 5G and IoT integration, ML models serve as a sophisticated defense mechanism, adept at identifying irregular patterns and potential threats within the vast network of interconnected devices (Lam and Abbas, 2020; Rahman *et al*., 2022). These models analyze network traffic and device behavior, enabling the swift identification of anomalies that could signal security breaches or unauthorized access attempts.

ML-driven intrusion detection systems are crucial in differentiating normal operational behavior from potentially malicious activities in real time. These systems continuously learn and adapt, evolving alongside emerging threats to bolster the resilience of the 5G-IoT ecosystem against cyber intrusions.

Moreover, the utilization of ML techniques during the design and development phases of IoT devices within 5G networks strengthens the security infrastructure. ML-driven secure-by-design principles enable the integration of robust security measures into the core of device functionality, enhancing protection against vulnerabilities and potential exploits.

This approach not only enhances the immediate threat detection capabilities but also facilitates a proactive stance against evolving cyber threats. By leveraging ML models for intrusion and anomaly detection, the 5G-IoT ecosystem can significantly mitigate security risks, preserving data integrity, and fostering a more secure environment for the proliferation of interconnected devices.

## Conclusion

As 5G technology is adopted, the integration with IoT devices has paved the way for transformative changes in various aspects of our daily lives. With increased connectivity, efficiency, and scalability, IoT devices are empowered to achieve unprecedented levels of performance. This has led to a surge in IoT applications, which have the potential to transform cities, industries, healthcare, transportation, homes, agriculture, and other sectors. Nonetheless, security concerns have surfaced, due to the increasing number of connected devices, which can lead to security threats. Consequently, the fusion of 5G and IoT needs to be carefully implemented, with security measures in place to ensure the safety and integrity of the network. The integration of IoT and 5G is essential for digital transformation and will continue to shape the world as we know it.

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