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Integration and Impact of 6G technology on IoT Devices

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Abstract **Review Article**

The transition to 6G wireless communication systems is poised to revolutionize the Internet of Things (IoT) by addressing the limitations of existing 5G networks and meeting the demands of emerging smart applications. This article explores the transformative potential of 6G technologies, emphasizing the necessity for enhanced wireless network properties to support the Internet of Everything (IoE). Key advancements include the integration of artificial intelligence for complex network optimization, utilization of the THz band for expansive spectrum resources, and the development of quantum communications. The paper highlights the recent trends and activities in 6G technology development, fundamental empowering innovation, and gives a comparative utilize case analysis between 5G and 6G systems. Furthermore, it talks about developing 6G network arrangements such as "holographic beam forming, AI-enabled IoT networks, edge computing, and backscatter communications," pointed at cultivating keen communities. Future inquire about bearings to achieve 6G-based IoT networks are too sketched out, clearing the way for a fully connected and intelligent world.

Keywords: 6G wireless communication, Internet of Things (IoT), Internet of Everything (IoE), artificial intelligence, THz band, quantum communication, edge computing, holographic beamforming.

INTRODUCTION

"Devices are hardware that have a wireless network connection and are integrated into equipment or other devices, so they can receive and share data over the internet or other networks. Examples of IoT devices include sensors, actuators, appliances and gadgets."

The rapid growth of Wi-Fi networking and intelligent systems, fueled by the emergence of the Internet of Things (IoT), has enabled significant transformative advancements. "The imminent arrival of sixth-generation (6G) wireless networks offers more opportunities as fifth-generation (5G) wireless networks improve IoT connections" Das et al., (2024).

Advances in smart loT devices and wireless communication technologies have empowered the creation of the IoT, which utilizes devices' far reaching detecting and communication/computing capability. "IoT is defined as a network of physical objects that includes hardware, software, sensors, and actuators." Its goal is to simplify the process of collecting and transmitting estimation of information to information centers for storage and analysis. Recent literature shows that IoT applications are utilized in several study areas including savvy cities, natural applications like weather and air quality forecasts, well-being, pipeline security, and smart agriculture. IoT is attracting significant attention from industry and academics as a ground breaking technology with the capacity to transform several aspects of the Internet in the future, Okumoku-Evroro (2015).

"Increasingly, IoT devices are utilizing AI and machine learning to bring insight and autonomy to systems and processes, such as autonomous driving, industrial smart manufacturing, medical equipment, and home automation. Many of these devices are small, power- and cost-constrained microcontroller-based systems. Network bandwidth and consumer expectations around data privacy and user experience continue to demand more on-device processing, where data is processed on the IoT endpoint, rather than using cloud-based approaches."

An example of an IoT device?

"Connected devices are part of an ecosystem in which every device talks to other related devices in the environment to automate home and industry tasks. They can transmit sensor

data to users, businesses and other intended parties. The devices can be characterized into three main groups: consumer, enterprise and industrial" Gillis n.d.

1) "Consumer-connected devices include smart TVs, smart speakers such as Google Home, toys, wearables and smart appliances. In a smart home, for example, IoT devices are created to detect and respond to a person's presence. When an individual arrives home, their car communicates with the garage to open the door." Schroeder, 2021.

2) "Enterprise IoT devices are edge devices created for businesses. There are a wide variety of enterprise IoT devices available. These devices differ in bilities but tend to be aimed at maintaining a facility or improving operational efficiency. Some options include smart locks, smart thermostats, smart lighting and smart security. In the enterprise, smart devices can help with meetings. Smart sensors placed in a conference room can help an employee locate and schedule an available room for a meeting, ensuring the proper room type, size and features are available." Schroeder, 2021.

3) "Industrial IoT (IIoT) devices are created to be utilized in factories or other industrial environments. Most IIoT devices are sensors utilize to monitor an assembly line or other manufacturing processes. Sensor data is transmitted to monitor applications to ensure key processes are running optimally. These same sensors can also prevent unexpected downtime by predicting when parts need to be replaced. If a problem occurs, the system can send a notification to a service technician informing them of what's wrong and what parts they need to fix the problem. This can save the technician from coming on-site to diagnose the problem and then having to travel to a warehouse to get the part needed to fix the problem." Schroeder, (2021).

4) In the medical industry, IoT devices are used to monitor a patient's health and track their vitals. If a patient needs attention, these monitors send notifications to the relevant healthcare workers." Schroeder, (2021).

Enhanced Connectivity and Data Rates

6G technology can be "defined as a network that operates in previously untapped radio frequencies and employs cognitive technologies such as AI, IoT, etc., to enable high-speed, low-latency communication multiple times faster than current fifth-generation networks.

This next-gen wireless network is created to assist various applications, from improved mobile broadband to mission-critical communications and Large-scale IoT implementation. The primary focus of this technology is to support the fourth industrial revolution, acting as a bridge between humans, machines, and nature.

With its capability to process multiple amounts of information here and now, 6G aims to foster advancement in smart cities, autonomous driving, deeply improved and virtual reality experiences, and much more, making way for a truly connected world. As a successor to 5G technology, the 6G development process is steering towards creating wireless technology that is expected to be much faster and more efficient. As per a Bloomberg Report, 6G is under research and development, with standards expected to be finalized by 2028 and widespread deployment around 2030.

For businesses, this new wave of technology aims to deliver a seamless, immersive experience across various domains, enabling devices to support previously unattainable tasks due to technological constraints. From healthcare's remote checking to manufacturing automation, 6G's potential to revolutionize every commerce operation is immense. Businesses must plan for 6G's arrival by investing in the right infrastructure and skills to leverage its benefits. This involves strategizing for 6G integration, investigating inventive trade models, and building partnerships for a smooth move to a 6G-driven computerized ecosystem.

Exploring the Positive Aspects of 6G Technology for Enterprises

As we approach a new era in technology, 6G technology is set to significantly enhance digital communication and connectivity. Here are the key benefits 6G technology offers, paving the way for innovation and efficiency.

Enhanced Network Reliability: 6G plans to nearly eradicate delays in information transmission, making it extremely reliable. This is especially important for important uses like self-driving cars and for performing surgeries remotely, where every second is important for professionals.

Ultra-Fast Data Speeds: 6G promises to skyrocket information speeds, making downloads immediate and improving the quality of streaming services. This improvement will lead to a effortless and more enjoyable on-stream experience across all types of digital platforms, enabling businesses to offer superior services and engage with their customers here and now.

Enhanced Connectivity: One of the most sought-after positive aspect of 6G technology is enhanced connectivity. This will allow businesses to streamline their operations and introduce innovative smart technology solutions, leading to more astute, more proficient services and improved customer experiences.

Revolutionary Application Development: "Revolutionary application development facilitated by 6G will open new avenues for businesses to innovate in delivering services, enhancing learning, healthcare, and entertainment encounter with exceptional clarity and responsiveness."

Energy Efficiency: "Beyond improving speed and connectivity, 6G also focuses on being more environmentally friendly. By optimizing how data is sent and grasping green

energy, 6G networks will offer assistance to reduce the natural impact of our growing digital world, offering businesses an economical edge."

Ultra-Reliable Low-Latency Communications (URLLC)

"Ultra-reliable and low latency communications is maybe the foremost challenging task because of its demanding requirements of low latency combined with ultra-high reliability. Using more resources to extend reliability will in turn increment the latency, and therefore a combination of different technologies like software-defined networking (SDN), virtual network slicing, and physical layer technologies are currently experimented for achieving uRLLC with various applications. This special issue solicited high-quality papers reporting on new techniques and concepts, standards, future applications, novel physical-layer solutions, network architectures, resource allocation schemes, and other issues, challenges, and promising solutions for ultra-high speed, low latency and reliable communications in 6G network" Mumtaz, Menon, and Ashraf , 2021.

Reduced Latency

Reducing latency in network systems is a critical aspect of improving real-time communication, particularly in high-demand applications such as "automated manufacturing, intelligent transportation, and healthcare." One key technique for lowering latency is the optimization of network architecture, focusing on factors such as traffic congestion and radio channel conditions. Research by authors like Lima et al. and Giordani et al. has identified methods such as better resource allocation and predictive traffic management to mitigate delays (Lima et al., 2023; Giordani et al., 2022). For example, in 5G networks, the incorporation of low-latency communication (LLC) protocols can drastically reduce end-to-end delays, making it suitable for ultra-reliable applications like autonomous driving and remote medical procedures.

Latency prediction techniques also play a vital role. Studies like those by Kharab et al. propose data-driven models for predicting latency based on network quality indicators (Kharab et al., 2022). By analyzing key performance indicators (KPIs) such as signal quality and resource block usage, these models can forecast potential delays and adjust network operations accordingly.

Such strategies are pivotal in assembling the exact necessities of modern, latency-sensitive applications and can contribute significantly to improving the execution of next-generation networks.

Impacts of Increased Bandwidth on Internet of Things (IoT) Devices in 6G Networks

One of the key impacts of increased bandwidth in 6G networks is the ability to assist a larger number of IoT devices. As numerous devices become connected to the internet, the demand for bandwidth continues to grow. With 6G technology, networks will be able to handle a much higher volume of data traffic, allowing for more devices to be connected simultaneously without sacrificing performance.

In addition to supporting more devices, the increased bandwidth of 6G networks will also enable faster data transfer speeds for IoT devices. Therefore devices will be capable of communicating with each other and with the cloud more quickly, leading to improved efficiency and responsiveness. For applications that require real-time information processing, such as "autonomous vehicles or industrial automation systems," this increase in speed could be a game-changer.

Another crucial aspect of 6G technology is the reduction in latency that it offers. "*Latency refers to the delay between when a command is sent from a device and when a response is received*." In this context of IoT devices, low latency is crucial for ensuring that devices can communicate with each other in real-time. With 6G networks, latency is expected to be reduced to just a few milliseconds, making it possible for devices to interact with each other almost instantaneously.

The combination of increased bandwidth and reduced latency in 6G networks will have a profound effect on the capabilities of IoT devices. For example, "in the healthcare industry, IoT devices could be utilized to check patients remotely and provide real-time feedback to healthcare providers." With 6G technology, these devices could transmit data more quickly and accurately, leading to improved patient outcomes.

Future Applications of 6G Speed and Latency Improvements in Various Industries

The development of 6G technology is on the horizon, promising even increased speeds and lower latency than the current 5G networks. With this advancement, various industries are poised to benefit from the improved connectivity and performance that 6G will bring. From healthcare to transportation, the applications of 6G speed and latency enhancements are vast and promising.

One industry that stands to benefit greatly from 6G technology is healthcare. With faster speeds and lower latency, medical professionals will be able to access and share patient information more quickly and efficiently. In the transportation industry, 6G speed and latency improvements could revolutionize the way we travel. Autonomous vehicles, for example, rely on fast and reliable connectivity to navigate roads and communicate with other vehicles.

The entertainment industry is another sector that will see significant benefits from 6G technology. With faster speeds and lower latency, streaming services could deliver high-quality content to viewers without buffering or lag. In the manufacturing industry, 6G speed and latency improvements could lead to more efficient and automated processes. With faster connectivity, machines and robots could communicate with each other more quickly, leading to increased productivity and reduced downtime. The education sector is also poised to benefit from 6G technology. With faster speeds and lower latency, students and teachers could access "online resources and collaborate on projects more easily. Virtual classrooms and

remote learning platforms" could be greatly enhanced with 6G technology, allowing for more interactive and engaging educational experiences.

Overall, the applications of 6G speed and latency enhancements are vast and promising. From healthcare to transportation, entertainment to manufacturing, and education, various industries stand to benefit from the improved connectivity and performance that 6G technology will bring. As we anticipate the future, it is clear that 6G technology will play a important role in shaping the way we live, work, and interact with the world around us.

Massive Machine-Type Communications (mMTC)

6G and IOT (Internet of Things) integration is poised to redefine the boundaries of connectivity, efficiency, and innovation. This transformative synergy between 6G and IoT is positioned to usher in an age of hyper connectivity, where devices not only connect but collaborate and make intelligent decisions in real time." Al-Ali & Yaacoub, 2023.

"As 6G technology continues to evolve, the support for Massive Machine-Type Communications (mMTC) is becoming increasingly important. mMTC is created to efficiently connect a vast number of devices, making it a key enabler for the Internet of Things (IoT) ecosystem. In the context provided by Al-Ali & Yaacoub (2023)," mMTC is categorized under "massive Machine Type Communications, offering reliable connectivity to a massive number of devices." Additionally, "ultra-Reliable and Low Latency Communication (uRLLC) applications are specifically tailored for mission-critical scenarios, emphasizing high reliability and extremely low latency requirements. The transition to 6G aims to support massive uRLLC (mURLLC), combining the needs of mMTC and uRLLC, as the number of IoT devices is projected to reach 25 billion by 2025" Al-Ali & Yaacoub, 2023.

The impact of mMTC on enhancing connectivity and communication capabilities in 6G networks

As 6G networks aim to revolutionize wireless communication, the integration of "*Massive Machine-Type Communications (mMTC)*" plays a pivotal role in enhancing connectivity and communication capabilities. mMTC, as highlighted by Al-Ali & Yaacoub (2023), is crucial for efficiently connecting a vast array of devices, making it a fundamental enabler for the Internet of Things (IoT) ecosystem. Moreover, ultra-Reliable and Low Latency Communication (uRLLC) applications are tailored for mission-critical scenarios with stringent reliability and latency requirements. "The shift to 6G emphasizes the support for massive uRLLC (mURLLC), amalgamating the needs of mMTC and uRLLC to cater to the projected surge in IoT devices, estimated to reach 25 billion by 2025" Al-Ali & Yaacoub, 2023. This convergence underscores the necessity of advancing robust communication technologies in 6G to address the multifaceted demands of future wireless networks.

Challenges and considerations for implementing mMTC in 6G technology

"6G networks are envisioned to revolutionize wireless communication by integrating Massive Machine-Type Communications (mMTC), which is crucial for efficiently connecting a vast array of devices, making it a fundamental enabler for the Internet of Things (IoT) ecosystem" Al-Ali & Yaacoub, 2023. Additionally, the incorporation of *"ultra-Reliable and Low Latency Communication (uRLLC)"* applications in 6G is tailored for mission-critical scenarios with stringent reliability and latency requirements. "The convergence of mMTC and uRLLC in 6G networks, as highlighted by Al-Ali & Yaacoub (2023)," aims to cater to the projected surge in IoT devices, estimated to reach 25 billion by 2025. This amalgamation underscores the necessity of advancing robust communication technologies in 6G to comply with the multifaceted demands for forthcoming wireless networks. In the realm of 6G technology, challenges and considerations arise when implementing mMTC capabilities. The seamless integration of mMTC into 6G networks requires addressing issues related to scalability, energy efficiency, and network reliability. Ensuring that the infrastructure can support the "massive connectivity" demands "of IoT devices while" maintaining low latency and high reliability is paramount (Gustavsson et al., 2021). Moreover, the development of efficient communication protocols and mechanisms for handling diverse data types and transmission requirements is essential to harness the maximum capacity of mMTC in 6G networks. By overcoming these challenges and carefully considering the implementation aspects, 6G technology can unleash the full capabilities of mMTC, clearing the way for a truly interconnected and intelligent future.

Future prospects and possibilities for leveraging mMTC in 6G networks

On the subject of 6G networks, the integration of "*massive Machine Type Communications (mMTC)*" presents a significant opportunity for advancing wireless communication capabilities. As highlighted by Gustavsson et al. (2021), the challenges in implementing mMTC in 6G networks revolve around scalability, energy efficiency, and network reliability. To fully leverage mMTC in 6G, robust communication technologies must be developed to support the increasing demands of IoT devices while maintaining the low latency and high reliability. Furthermore, the development of efficient communication protocols tailored to diverse data types and transmission requirements is crucial for unlocking potential of mMTC in future wireless networks. "By addressing these challenges thoughtfully, 6G technology can pave the way for a highly interconnected and intelligent future, providing seamless connectivity for a vast array of applications" Gustavsson et al., 2021; Al-Ali & Yaacoub, 2023. "It is anticipated that mMTC and URLLC services will evolve into umMTC (ultra-massive Machine-Type Communication) and eRLLC (extremely Reliable Low-Latency Communication), respectively," Ji et al 2021, Alwis et al 2021, & Alsharif et al 2020.

Increased Device Density

The integration of Artificial Intelligence (AI) in the development of 6G technology is expected to revolutionize communication networks by enhancing human intelligence, improving experiences, and ultimately, the quality of life. As highlighted by Raihan (2023), the implementation of 6G technology will involve various cutting-edge supports such as edge technology, cloud computing, and blockchain, enabling seamless communication between devices through low-earth orbit and satellite communication (Khan et al., 2022). This advancement aims to integrate computation, routing, and detection into communication networks, emphasizing safety by addressing security, confidentiality, and data protection concerns (Chavhan, 2022). Moreover, leveraging Machine Learning (ML) in 6G technology can optimize cellular networks and provide devices with vantage points for both advantageous and potential detrimental use (Zappone et al., 2019).

As the 6G communication network continues to evolve, it is crucial to consider the implications of incorporating AI into its framework. "The convergence of AI and 6G networking technology is projected to usher in a new era where interconnected devices transition into interconnected intelligent systems" Raihan, 2023. This transformative shift not only enhances connectivity but also improves the overall user experience by enabling seamless communication across various devices and systems (Zappone et al., 2019). Additionally, "the optimization of cellular networks through ML applications can significantly impact the efficient transmission and processing of vast amounts of data, albeit with potential security vulnerabilities that need to be addressed" Zappone et al., 2019. In conclusion, the symbiotic relationship between AI and 6G technology holds immense promise in shaping the future of communication networks, offering unprecedented opportunities for technology and advancement in various domains.

Impact of increased device density on network performance and capacity

The increasing device density in networks poses significant challenges to network performance and capacity. Incorporating artificial intelligence (AI) into the framework of 6G communication networks can help address these challenges. Raihan (2023) highlights that the integration of AI and 6G technology is set to transform interconnected devices into intelligent systems, paving the way for improved connectivity and user experiences. This shift not only streamlines communication across various systems but also enhances the overall quality of service. Moreover, Zappone et al. (2019) emphasize the role of machine learning applications in optimizing cellular networks, facilitating efficient data transmission and processing, although potential security concerns need to be mitigated. The synergy between AI and 6G technologies offers vast opportunities for innovation and advancement in network performance and capacity.

Increased Device Density: "6G will significantly enhance the capacity for connecting more devices within a given area. The projected increase from 1 million devices per square kilometer in 5G to 10 million in 6G will support the vast ecosystems of IoT devices, facilitating seamless communication and coordination among them, Kelsey (2024)."

Energy Efficiency and Sustainability

i. **Energy Optimization**: "6G networks will employ AI and machine learning to optimize power management, reducing energy consumption across the network. This not only extends the battery life of IoT devices but also minimizes the environmental impact of maintaining extensive IoT networks, Polymeni et al (2023)."

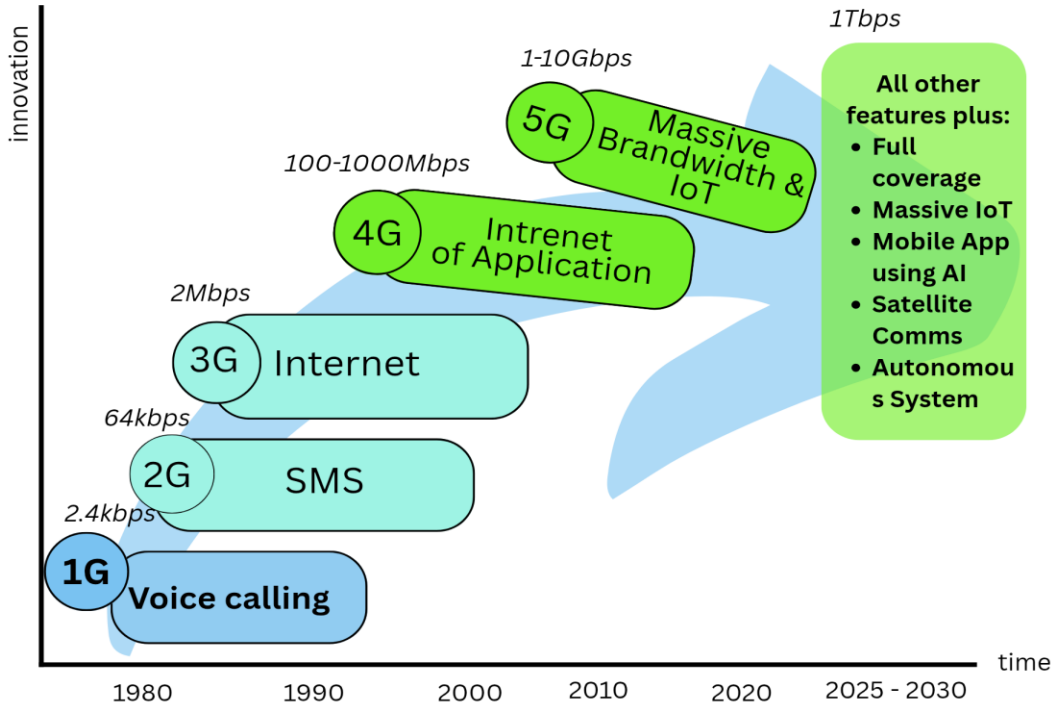

Plate 1. "The evolution of wireless communications toward future 6G networks and applications, Polymeni et al (2023)."

ii. **Energy Harvesting**: Technologies like ambient backscatter communications and energy harvesting will enable IoT devices to capture and utilize ambient energy sources, such as light and motion, making them more sustainable and reducing the need for frequent battery replacements, Polymeni et al (2023).

Advanced AI integration

"Artificial intelligence (AI) is a branch of computer science that develops and researches methods and software that allow machines to sense their surroundings and use learning and intelligence to take actions that increase their chances of attaining specific goals. AI is the result of the development of devices that have a level of intelligence like humans" — Saputra et al., 2023. AI equips businesses with sophisticated "tools and skills that help them make better decisions and spend less time on monotonous chores. With the help of AI, a well-equipped life is generated where the automated machines work for humans, saving their time and energy" — Ghosh & Thirugnanam, 2021.

"Deep Learning (DL) is a subset of Machine Learning (ML), which itself is a subset of artificial intelligence." According to Marpai Report, many use DL and ML interchangeably as they function similarly, but DL is a more advanced version of ML/AI. DL enables machines to learn without human supervision, allowing them to identify speech, translate languages, detect objects, and even make data-driven judgments. Integrating AI is vital because it allows firms to streamline processes and detect bottlenecks. Integrative AI aims to combine AI technologies to advance beyond their own strengths while compensating for their respective deficiencies. AI integration improves decision-making using Lean Analytics. AI can process and analyze large volumes of data much faster and more precisely than humans. "**Fujitsu connection** report that a great example of AI in action is in scanning vast amounts Internet traffic in real time, helping identify potential cybersecurity threats that have never even been seen before, which allows us to take mitigating actions before a threat has taken hold." Advanced AI integration improves the capabilities of Intelligent IoT Networks by "allowing for real-time data analysis, decision-making, and automation" Saputra et al., 2023.

Intelligent Internet of Things (IOTs) Networks

"The Internet of Things refers to billions of physical items that are now connected to the Internet and transmit data without the need for human-to-human or human-to-computer interaction." The Internet of Things (IoT) has emerged as a revolutionary invention, connecting the physical and digital worlds and having a substantial impact on many parts of daily life. IoT devices can autonomously send data across a network without human intervention. "AIoT refers to the merging of artificial intelligence (AI) technologies and internet of things (IoT) infrastructure. The merging of (AI) and the (IoT) constitutes a rapidly advancing and transformative field known as AIoT (Artificial Intelligence of Things)" Gouiza et al., 2024. IoT networks make use of advanced technologies like artificial intelligence (AI), machine learning, edge computing, and cloud computing to improve the functionality and intelligence of its devices, Okumoku-Evroro (2016).

"Intelligent Internet of Things (IoT) networks, the most recent of which is the 6th Generation of the Internet of Things (6G-IoT), are expected to serve as the foundation for the next generation of IoT, providing the infrastructure required for billions of devices to connect, communicate, and collaborate at unprecedented speeds and reliability. Various global research institutions have focused attention on the 6G networks as the 5G networks have entered the commercial deployment phase" Zakria et al., 2023. "The merger of 6G and IoT is more than just a technology update; it is a paradigm change toward an interconnected future with limitless opportunities for innovation. 6G networking combines current and emerging technologies from the physical to the application network levels, creating a fully digitized and unified interface among users, services, computers, sensors, and smart objects in response to the new era's challenges" Sofia et al., 2023; Guo et al., 2021.

Improved security and privacy

"Privacy refers to your right to control your personal information, whereas security refers to the protection of such information." As the number of IoT devices grows, it is critical to ensure their security and privacy. "Security issues have been characterized into sensitive data access, data segregation, privacy, bug exploitation, recovery, accountability, malicious insiders, management console security, account control, and multi-tenancy issues" Shyam & Amit, 2016. "Security attacks are often the main motivations that drive how security systems in the next generation should be changed to counter the exploit of old vulnerabilities" Van-Linh et al., 2021. 6G networks will have sophisticated security protocols and encryption technologies to secure information and maintain privacy, laying the groundwork for IoT devices to operate securely. Using AI-driven algorithms for real-time threat identification and response, 6G networks may achieve hitherto impossible levels of proactive security management.

Enhanced security protocols

A security protocol is a series of activities designed to secure data. Implementing network security protocols helped to mitigate potential security threats. Enhanced Security is a procedure for delivering additional security beyond what the Provider offers, which trading partners may choose to employ. This can be accomplished by implementing all of the security layers that we have. Enhanced security measures increase user trust, resulting in wider adoption of IoT devices. By using these upgraded security standards, enterprises may greatly enhanced the security and privacy of their Intelligent IoT Networks, assuring dependable and secure operation.

Use Cases and Applications of 6G-Enabled IoT

The arrival of 6G technology is expected to transform the Internet of Things (IoT) landscape, enabling advanced applications with extremely fast speeds, high capacity, and minimal latency. With its ability to support extensive data sharing and instant communication, 6G technology is poised to unlock new IoT applications that require real-time response, high data rates, and connectivity in remote or challenging environments. Patel, R. (2022). "6G will bring significant advancements across sectors such as smart cities, healthcare, industrial IoT, and agriculture, further bridging the gap between digital and physical realms" Lee, H., & Kim, S. 2023.

Smart Cities

"6G is expected to enable a new level of smart city infrastructure, bringing together connected systems for efficient city management, environmental monitoring, and improved quality of life for urban residents" Zhang & Lu, 2022.

Traffic Management and Autonomous Vehicles: Traffic congestion is a major challenge in urban areas. With 6G, cities can deploy "advanced traffic management systems that optimize traffic flow and reduce accidents. The low latency and high reliability of 6G will support real-time communication between autonomous vehicles and traffic infrastructure, ensuring a seamless, coordinated transportation system" Smith, 2023.

Energy Optimization and Smart Grids: "Smart grids connected via 6G will be able to adjust energy distribution dynamically based on real-time demand data, leading to more efficient energy usage and reduced costs. By analyzing data from 6G-connected sensors, cities can adjust electricity distribution, reduce waste, and improve sustainability" (Smith, 2023).

Public Safety and Surveillance: 6G-enabled IoT devices will support advanced surveillance systems, enhancing public safety through faster response times. Video analytics can be processed in real time, aiding law enforcement and emergency services (Zhang & Lu, 2022).

Healthcare

"6G technology has the ability to transform healthcare by enabling real-time monitoring, remote diagnostics, and even remote surgeries. The enhanced data speeds and ultra-low latency of 6G are crucial for handling the increasing volume of medical data from IoT devices" Lee & Kim, 2023.

Remote Surgery and Telemedicine: With 6G's low latency, remote surgeries can become a practical reality. Surgeons can perform procedures on patients across the globe using robotic systems that respond instantly, providing critical care to underserved areas. Telemedicine applications will also benefit from 6G, enabling high-quality video streaming and real-time patient monitoring (Lee & Kim, 2023).

Wearable Health Devices and Monitoring: 6G will enhance wearable devices by enabling continuous, real-time health monitoring for patients. Data on vital signs, physical activity, and even biochemical markers can be transmitted instantly to healthcare providers, facilitating timely interventions. This capability is expected to improve preventive care and chronic disease management (White & Chan, 2024).

Medical Imaging and Data Processing: High-resolution imaging in diagnostics will see a major boost with 6G. The large data files from MRI and CT scans can be quickly transmitted

and analyzed using AI, potentially speeding up diagnosis and treatment decisions (Lee & Kim, 2023).

Industrial IoT

"Industrial IoT (IIoT) applications will thrive with 6G due to its ability to support massive machine-type communication (mMTC) and extremely reliable low-latency communication (URLLC). These features are essential for smart manufacturing and automated industrial processes" Patel, 2022.

Smart Manufacturing and Automation: In 6G-enabled factories, automated machinery will be interconnected, allowing real-time data exchange. This connectivity enables predictive maintenance, where machines can report issues before they lead to breakdowns, reducing downtime and enhancing productivity. 6G's high bandwidth will also support the use of augmented reality (AR) in training and maintenance (Patel, 2022).

Remote Monitoring and Quality Control: "Industrial operations can leverage 6G for real-time monitoring and control of remote equipment. This capability allows industries to manage multiple sites with fewer on-site workers, enhancing safety and efficiency. Sensors can detect issues with equipment performance and instantly report to managers for immediate action" (Thompson, 2023).

Supply Chain Optimization: The increased speed of 6G will enhance supply chain logistics by providing end-to-end visibility across global networks. Real-time tracking of shipments, goods, and materials will help companies respond to supply chain disruptions more effectively, allowing for better inventory management and delivery optimization (White & Chan, 2024).

Agriculture

6G technology will support precision agriculture, transforming traditional farming into a data-driven, automated industry. IoT devices enabled by 6G will provide farmers with valuable insights, improving yield, reducing costs, and addressing environmental challenges (Wilson, 2023).

Precision Farming: "6G will enable real-time checking of soil health, moisture levels, and crop conditions using IoT sensors. This information allows farmers to apply water, fertilizers, and pesticides only where needed, reducing waste and environmental impact. Advanced analytics can also help farmers make decisions on optimal planting and harvesting times" Wilson, 2023.

Autonomous Machinery: With 6G, autonomous tractors, drones, and other farming equipment can operate efficiently across large fields. These machines can coordinate with each other in real time, performing complex tasks such as planting, watering, and harvesting with minimal human intervention. 6G coverage in rural areas will be essential to fully realize this potential (Morales & Turner, 2023).

Livestock Monitoring and Health Management: IoT-enabled health monitoring systems can track livestock's physical conditions, alerting farmers to issues such as illness or nutritional deficiencies. This proactive approach to animal health management can improve livestock well-being and productivity, ultimately contributing to food security (Wilson, 2023).

CONCLUSION

The adaptation of 6G technology into IoT devices across various sectors will transform traditional practices and enhance efficiency, connectivity, and data-driven insights. As 6G continues to develop, its potential to redefine the IoT landscape in smart cities, healthcare, industrial IoT, and agriculture holds tremendous promise for a more connected and intelligent future.

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