DECENTRALIZED SYSTEMS AND NEXT-GENERATION INTERNET

DEVELOPMENT OF 6G NETWORKS AND TECHNOLOGY

Edited By

Suman Lata Tripathi, Mufti Mahmud, C. Narmadha, and S. Albert Alexander

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Decentralized Systems and Next-Generation Internet

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Scope: Next Generation Internet (NGI) is the focus of countries like the US and UK towards the improvement and revolution in the present and future internet with its backend networks and infrastructure to develop faster, reliable, secure internet platforms. The objective of NGI is to develop an advanced version of the internet. The target deliverables of NGI include building network communication architecture with enhanced levels of data access, human communication and productivity and achieving substantially and faster internet bandwidth and speed. An evolution of the internet from a low-level focus to higher level focus on interconnectivity, increased user interactions, video chat, and financial and social interactions in the virtual world are the major objectives towards development of NGI. A virtual world which is not owned or controlled by a single entity or metaverse in that a computer-generated virtual environment is created for reliable user interactions. Web 3.0 is an advancement that will control tomorrow's internet and metaverse centers for better user experiences. In the metaverse, users interacting using software from different vendors will experience monetization by each vendor with seamless interactions in spite of different technologies.

This series covers the information from the ground level of requirements for internet-based user interactions, platforms and applications leading to the development of next-generation internet. Future requirements and dependencies on more online activities will need to work more on developing decentralized systems to improve user experience with speedy, reliable and secured interactions in a virtual environment. This series will provide the opportunity to the academician and industry professionals to share their knowledge and experiences with learners and practitioners relevant to diverse areas of improvements for the development of next-generation internet and decentralized systems or metaverse.

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Preface

Exploring the benefits of 5G and beyond 5G along with the challenges associated with 5G play a key role in the development of next-generation internet. 6G is targeted to improve download speeds, eliminate latency, reduce congestion on mobile networks, and support advancements in technology. 6G has the potential to transform how the human, physical, and digital worlds interact with each other. 6G has the capability to support advancements in technology, such as virtual reality (VR), augmented reality (AR), metaverse, and artificial intelligence (AI). Machine learning and deep learning modules are also now an integral part of almost automated systems where signal processing is performed at different levels. Signal processing in the form of text, image, or video needs large data computational operations at the desired data rate and accuracy. Large data require more use of IC area with embedded bulk memories that further lead to power consumption. Trade-offs between power consumption, delay, and IC area are always a concern of designers and researchers. Energy-efficient high-speed data processing is required in major areas like biomedicine or healthcare, agriculture, transport, climate change and national security, and defense applications. This book will provide a foundation and initial inputs to researchers, scholars, and students working in the area of wireless network and high-speed data processing systems. Moreover, it will provide techniques, tools, and methodology to develop next-generation internet and 6G.

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1

Introduction to AI Techniques for 6G Application

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Abstract

The sixth generation (6G) wireless communication network aims to revolutionize connectivity by seamlessly integrating terrestrial, aerial, and maritime communications. With its promise of enhanced reliability, speed, and support for a massive number of devices with ultra-low latency necessities, researchers are exploring cutting-edge technologies such as quantum communication, machine learning (ML), artificial intelligence (AI), blockchain, millimeter waves, terahertz communication, tactile internet, and small cell communication. It highlights various applications and use cases of the 6G networks across different aspects and discusses key performance indicators for beyond 5G and 6G networks. The next-generation wireless communication technology, 6G, promises to revolutionize connectivity, data exchange, and the deployment of intelligent applications. With plenty of Internet of Things devices, autonomous systems, and immersive technologies, there is a growing need for advanced AI techniques to harness the full potential of 6G networks.

The standardization activities for fifth-generation (5G) communication systems have concluded, and global deployment of 5G networks is already underway. To maintain a competitive edge in wireless networks and prepare for the communication requirements of the 2030s, collaboration between academia and industry has begun to envision the future generation of communication systems, commonly referred to as sixth generation (6G). The aim is to establish a foundation that addresses the evolving requirements of future communication. This chapter consists of the transformative potential of AI techniques in 6G networks, enabling advanced applications, efficient resource utilization, and intelligent

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decision-making. It emphasizes the need for continued research and collaboration to face the challenges and harness the benefits of AI for the future of 6G.

Keywords: 5G, 6G, AI, IoT, ML, MIMO

1.1 Introduction

The sixth generation (6G) is expected to bring about a revolutionary transformation in wireless connectivity, surpassing the capabilities of its predecessor [1–3]. It aims to provide unprecedented data rates, ultra-low latency, massive device connectivity, enhanced energy efficiency, and advanced network intelligence. These advancements will enable a wide range of transformative innovation in various sectors such as healthcare, transportation, manufacturing, entertainment, and beyond [4–7].

One of the most influencing factors behind the development of 6G is the ever-growing demand for data-intensive applications and the exponential growth of IoT devices. With the proliferation of connected devices, including sensors, wearables, and autonomous vehicles, a communication infrastructure that can support the massive scale and diverse requirements of these devices seamlessly is needed [8–10].

Beyond higher data rates and lower latency, 6G is expected to introduce new technological paradigms. This include the utilization of terahertz (THz) frequencies, advanced antenna technologies, i.e., massive MIMO (multiple-input multiple-output), and beamforming techniques. Moreover, 6G is likely to leverage artificial intelligence (AI) algorithms to enhance network performance, improve resource allocation, and enable intelligent and context-aware communication [11–14].

The development and research of 6G are still in its early stages, with various academic institutions, industry players, and standardization bodies actively involved in shaping its future. As the demand for higher data rates, greater connectivity, and more advanced services continues to grow, the anticipation and exploration of 6G technology will pave the way for the future generation of wireless systems [15–18].

Figure 1.1 shows the 6G vision of the connected world. Future-generation communication systems are striving to obtain several key objectives, including high spectral and energy efficiency, and low latency [7–9]. This is primarily driven by the exponential growth of Internet of Things (IoT) devices. These devices are expected to enable innovative facilities such as smart traffic management, virtual reality (VR), environmental monitoring, digital sensing, telemedicine and high-definition (HD),

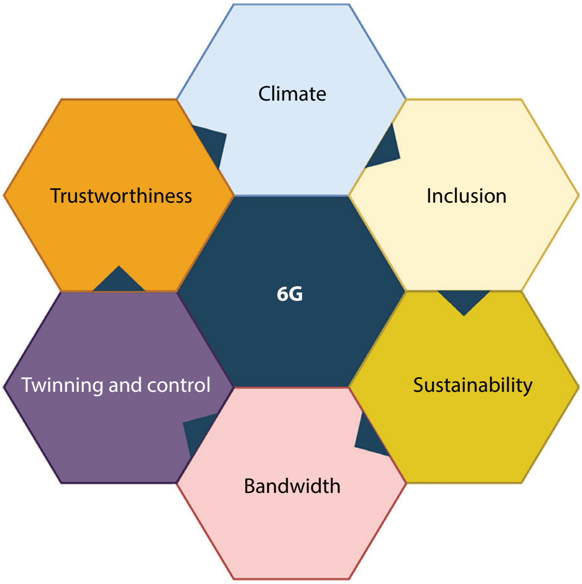

Figure 1.1 The 6G vision of the connected world.

and full HD image transmission in connected smart robots and drones. Industry predictions estimate that the number of IoT devices will achieve 20 billion by 2025. Accommodating a substantial number of devices poses significant challenges for existing multiple access techniques, including the latest 5G (fifth-generation) communication systems. The 5G system is currently being deployed worldwide. Consequently, the third-generation partnership project, the organization responsible for developing 5G standards, has identified three key use cases for 5G as ultra-reliable and low latency communication, massive machine-type communication, and enhanced mobile broadband [1, 2].

Simultaneously, research efforts are underway to develop algorithms and technologies for the future aspects of communication systems. It will surpass the operation of existing 5G networks. In general, a 5G communication system supports up to 50,000 IoT devices per cell, and the design of future beyond 5G/6G communication systems necessitates even more robust networks to enable massive device connectivity. Extensive literature is emerging on various aspects of 6G networks, aiming to address the challenges and opportunities presented by these future systems [16–23].

6G of wireless communication systems is envisioned as the next frontier in mobile communication technology. Recently, 5G networks are being adopted globally. Researchers and industry experts have already begun exploring the potential requirements, capabilities, and applications of 6G [15].

1.2 Different Generation of Communication: From 1G to 6G

Wireless communication has evolved significantly over the years, with each generation bringing advancements in speed, capacity, and capabilities. Figure 1.2 shows the different generations of communications. An overview of the evolution of wireless communication from 1G to 6G is discussed below.

1.2.1 First Generation (1G)

1G was introduced in the 1980s. It is the first commercial analog cellular system. It used analog signals for voice communication and offered limited capacity and low-quality voice calls.

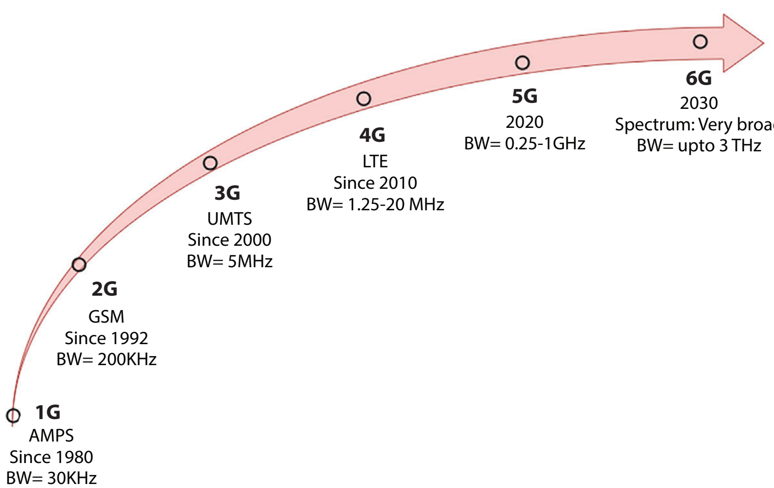

Figure 1.2 Different generations of communications.