# CURRENT AND FUTURE CELLULAR SYSTEMS

## TECHNOLOGIES, APPLICATIONS, AND CHALLENGES

EDITED BY
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# Current and Future Cellular Systems

Technologies, Applications, and Challenges

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**Suhaib Ahmed**
Dr. Suhaib Ahmed is currently working as an assistant professor and faculty-in-charge, Centre for Research, Innovation and Entrepreneurship, Model Institute of Engineering and Technology, Jammu, India. He received his BE degree in Electronics and Communication Engineering from University of Jammu, India, in 2012, MTech and PhD degrees in Electronics and Communication Engineering from Shri Mata Vaishno Devi University, Katra, India, in 2014 and 2019, respectively. His research interests include quantum-dot cellular automata, nano-electronics, VLSI, data converters, nanotechnology, wireless sensor networks, IoT, AI/ML, bioelectronics, and signal processing. Dr. Ahmed is a Senior Member of IEEE, Life Member of IETE, ISTE, and Computer Society of India. He has published around 90 research papers in reputed peer-reviewed journals of IEEE, Springer, Elsevier, Wiley, etc. and in various international/national

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**Shalli Rani**

Dr. Shalli Rani completed her post doctorate from Manchester Metropolitan University, UK, in June, 2023. She is professor in Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, Punjab, India. She has 18+ years of teaching experience. She received MCA degree from Maharishi Dayanand University, Rohtak, in 2004 and the MTech degree in Computer Science from Janardan Rai Nagar Vidyapeeth University, Udaipur, in 2007, and PhD degree in Computer Applications from Punjab Technical University, Jalandhar, in 2017. Her main area of interest and research are Wireless Sensor Networks, Underwater Sensor networks, Machine Learning, and Internet of Things. She has published/accepted/presented more than 100+ papers in international journals/conferences (SCI+Scopus) and edited/authored five books with international publishers. She is serving as the associate editor of *IEEE Future Directions Letters*. She served as a guest editor in *IEEE Transaction on Industrial Informatics*, Hindawi, WCMC, and Elsevier IoT Journals. She has also served as reviewer in many repudiated journals of IEEE, Springer, Elsevier, IET, Hindawi, and Wiley. She has worked on Big Data, Underwater Acoustic Sensors, and IoT to show the importance of WSN in IoT applications. She received a Young Scientist Award in February 2014 from Punjab Science Congress, Lifetime Achievement Award, and Supervisor of the Year Award from Global Innovation and Excellence, 2021.

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# Preface

The explosive demand for high data rates by users, coupled with the rapid development of data-intensive applications, has pushed the boundaries of current cellular technologies. The evolution from 1G to 5G has been transformative, but it has also revealed the limitations of these systems in addressing the diverse needs of future networks. As we approach the era of 5G and beyond, there is a growing realization that these technologies are no longer confined to a single domain. They encompass a wide range of applications, each with unique requirements, bringing about new challenges that demand innovative solutions.

This book provides a comprehensive examination of emerging technologies and the challenges faced in the deployment of 5G and beyond. It highlights the latest trends in resource allocation, power optimization, and the role of artificial intelligence (AI) and machine learning (ML) in enhancing quality of service (QoS) and decision-making processes in complex systems such as autonomous vehicles, resource allocation, and power management. The content aims to address the architectural and deployment challenges posed by the increasing heterogeneity of devices and user demands, offering insights into how future networks can evolve to meet these requirements.

The scope of this book spans several key areas, beginning with an overview of the evolution of cellular communication, technological advancements from 1G to 5G, and the critical architectural challenges that remain. A detailed discussion on resource allocation and power optimization for 5G and beyond is provided, exploring techniques and solutions that address the growing complexity of modern cellular networks. Additionally, the growing role of AI and ML in 5G networks is examined, showcasing how these technologies can assist in areas like resource assignment, power optimization, and autonomous decision-making.

Furthermore, the book investigates into the cutting-edge domain of millimeter wave (mmWave) communication, outlining the latest trends and challenges in high-frequency communication, i.e. Terahertz frequencies (THz), systems. Moreover, it also discusses the evolving technologies and highlights the new

applications in the 5G domain. This book not only provides a clear understanding of the current state of 5G technology but also inspires future research and innovation. It is our hope that this book will serve as a guide for both seasoned professionals and newcomers to the field, helping them navigate the complexities of future networks and contribute to the advancement of next-generation communication technologies.

## Glossary

- **5G Network:** The fifth generation of mobile network technology offering enhanced speed, reliability, and connectivity for applications such as IoT, autonomous vehicles, and smart cities.
- **6G Network:** The anticipated sixth generation of wireless communication technology, expected to provide ultra-high data rates, low latency, and massive device connectivity by 2030.
- **IoT (Internet of Things):** A network of interconnected devices that communicate and exchange data autonomously, often used in industries such as healthcare, transportation, and home automation.
- **Edge Computing:** A computing paradigm that processes data near its source to reduce latency, improve efficiency, and enhance real-time decision-making capabilities.
- **Machine Learning (ML):** A branch of artificial intelligence that enables systems to learn and improve from data without explicit programming, used for predictive analytics and decision-making.
- **Deep Learning (DL):** A subset of machine learning involving neural networks with many layers, used for tasks such as intrusion detection and image recognition.
- **Spectrum Sharing:** A technique for efficient use of radio frequency spectrum by allowing multiple users or devices to share the same frequency bands dynamically.
- **Cognitive Radio:** A radio technology that intelligently detects unused spectrum and adjusts transmission parameters to optimize utilization without interfering with primary users.
- **Handover (HO):** A process in wireless communication where a mobile device switches connection from one base station to another to maintain seamless connectivity.
- **Distributed Denial of Service (DDoS):** A cyberattack where multiple systems overwhelm a target, such as a server or network, causing disruption of services.

- **Network Slicing:** A 5G feature that creates multiple virtual networks on a shared physical infrastructure to cater to specific use cases with different requirements.
- **Artificial Intelligence (AI):** The simulation of human intelligence processes by machines, especially computer systems, enabling tasks like learning, reasoning, and self-correction.
- **Cybersecurity:** The practice of protecting systems, networks, and data from digital attacks, unauthorized access, and damage.
- **Blockchain:** A decentralized digital ledger technology used for secure and transparent data recording and verification across distributed networks.
- **Non-orthogonal Multiple Access (NOMA):** A multiple access technique allowing multiple users to share the same resources (frequency/time) by allocating different power levels to optimize spectral efficiency.
- **Interference Mitigation:** Strategies and techniques to reduce or eliminate signal interference in wireless communication systems to improve performance.
- **Dynamic Spectrum Access (DSA):** A method that allows unlicensed users to access spectrum dynamically based on availability and usage patterns.