Foreword

5G networks are being built and expanded worldwide. Compared to 4G, they not only offer obvious advantages such as higher bit rates but also high reliability and low latency, e.g., for car-to-x applications, or the integration of a very high number of end devices, such as sensors in a smart city.

To understand and sufficiently appreciate this, Chapters 1 and 2 follow the evolutionary development steps of mobile networks. This includes an overview of 2G and 3G with the different 3GPP (3rd Generation Partnership Project) releases, the introduction of the NGN (Next Generation Network) concept with VoIP (Voice over IP), the corresponding protocols SIP (Session Initiation Protocol), H.248 and Diameter, as well as the IMS (IP Multimedia Subsystem) to provide Multimedia over IP real-time services. A look at 4G with SAE (System Architecture Evolution) and LTE (Long Term Evolution), including VoLTE (Voice over LTE), completes the overview of the continuous development of mobile networks.

Starting with 4G, the increasing use of new network technologies such as NFV (Network Functions Virtualisation) and MEC (Multi-access Edge Computing), as well as SDN (Software Defined Networking) and SFC (Service Function Chaining), has become evident. Chapter 3 is dedicated to these essential technologies to implement the concept of so-called Future Networks and, consequently, 5G systems. The book's second edition provides enhancements and improvements on the topics of C-RAN (Cloud-Radio Access Network) and SDN.

The approach to 5G is different from previous mobile network versions, which were mainly driven by technology. As can be seen in Chapter 4, 5G started with possible use cases and deployment scenarios. Based on these, the requirements for the different application areas were derived, and only then the concepts and techniques required for the implementation were specified. The standardization is done in releases, as is usual with 3GPP. Releases 15, 16, and 17 have been completely standardized, Release 18 is in progress, and Release 19 has been started. In this context, as explained in Chapter 5, the ITU (International Telecommunication Union) should be mentioned in particular. It has defined a 5G target system based on the requirements and identified possible frequency ranges for 5G. These, in turn, have been and are still allocated to the network operators by regulators. The 2nd edition of the book brings updates on this, introducing, for example, Release 17, discussing the advantages and disadvantages of the various frequency ranges that can be used for 5G, extending the regulatory view to the EU and the USA, and providing an overview of the global 5G network rollout.

Chapter 6 provides an overview of a 5G system based on the applied design principles, the implementation features and associated functions, now also for Releases 16 and 17, and the resulting network architecture. Then, the technical details are worked out.

Chapter 7 provides deeper insights into the 5G access networks, focusing on the extremely powerful radio transmission technology, as well as discussing the topologies, architectures, and protocols of the RAN (Radio Access Network). A separate section on the increasingly important topic of O-RAN (Open-RAN) has been included in the 2nd edition of the book.

The highly innovative 5G core network is the subject of Chapter 8, where we discuss new topics such as Service Based Architecture (SBA) and Network Slicing. This central chapter has been significantly expanded in the 2nd edition of the book. It now contains descriptions of the signaling and user data protocol stacks. The usage of a UPF (User Plane Function) is discussed, especially for applications with high availability and latency requirements. In addition, new network functions introduced with Release 16 are explained, and the topic of network slicing is presented in more detail. In addition, the innovative opportunities for 3rd party providers through the network exposure functions with access to in-network functionalities are discussed. These extensions of Chapter 8 are completed by message captures from a real 5G system.

Chapter 9 summarizes the previously introduced concepts in an overall view, considering the 4G/5G migration, the use of the IMS in a 5G system, and the connection of various wired and wireless access networks up to satellite-supported base stations. The result is a network that implements FMC (Fixed Mobile Convergence) with only one core network technology. This is why 5G is not just a mobile network but also a new-generation converged network. The 2nd edition of the book complements this overall system view with two new sections on the topics of 5G and IoT (Internet of Things), including Time Sensitive Networking (TSN) and 5G campus networks. This chapter is concluded by an evaluation of 5G, including a comparison with 4G.

Since a 5G system is still an IP network, we must pay special attention to IT security by Chapter 10. A distinction is made between security for the communication network itself, security in the cloud infrastructure of the network operator, and the 3GPP security architecture standardized specifically for 5G. In the second edition, an update was made for the new releases and the Open-RAN.

This introduction to the 5th generation mobile networks is completed with an outline of the environmental influences due to electromagnetic radiation and the energy and raw material resources requirements in Chapter 11. Both subjects have been updated in the 2nd edition of the book. A new topic here is sustainability regarding a 5G system and its contribution to various areas of society and economic sectors. This is based on the 17 UN Sustainable Development Goals.

With the second edition, Chapter 12 finally provides a very detailed outlook on the future with the further development of 5G in Releases 18 and 19 at 3GPP, the work on a Network 2030 at the ITU, and activities and research results on 6G. In particular, 6G is examined in detail in four sections, starting with an overview of the organizations, initiatives, and research associations active in this area worldwide and regionally. The requirements for 6G are derived from use cases and deployment scenarios.

Subsequently, technologies and network architectures for implementation are discussed. In summary, a comparison of 6G with 5G is already being made at this early stage.

The book's main objective is to provide people interested in 5G technology and application scenarios with well-founded knowledge for an introduction to 5G and encourage further discussion of this topic. For this, the book refers to numerous additional sources in the 2nd edition, i.e., to 275 instead of 205 sources. The audience addressed by this book includes persons with a general interest in technology, primarily employees of public and private network operators. This book should be of particular interest within the IT departments of potential 5G user companies and, of course, among computer science and electrical engineering students. In addition, this book offers an optimally prepared introduction to the new topic of 6G.

For more information about this book, please visit the website www.5to6g.com. You are welcome to send me comments, suggestions, and questions by e-mail (trick@5to6g.com).

I especially want to thank my long-time companion, Prof. Dr. Armin Lehmann. On the one hand, he has contributed valuable technical impulses to this book, has been a constant discussion partner, and has critically reviewed the entire manuscript. On the other hand, together with M. Eng. Gregor Frick, he implemented a 5G system based on open source software and thus provided the already mentioned direct practical relevance. Many thanks to Gregor Frick for this support.

For the 2nd edition of the book, I would again like to thank Dr. Gerd Zimmermann, a proven 5G and experienced 3GPP standardization expert. Once again, he provided me with excellent support and advice.

Regarding the English edition, I would like to thank Gentiana Coman, Master in Computer Science. Without her comprehensive review covering all chapters, this English-language 5G book edition would not have been possible. I would also like to thank Dr. Besfort Shala, an expert in networks, IT security, and blockchain, for his helpful, careful, and critical review of the manuscript.

Last but not least, I would like to thank the De Gruyter publishing house. Dr. Damiano Sacco has initiated this 2nd edition of the 5G book; Mrs. Ute Skambraks was again very supportive during the complete book project; Mrs. Eva Kolla accompanied the work on this book up to the production. Many thanks to all of you for your support, excellent cooperation, and the well-designed cover.

Frankfurt/Main in October 2023   Ulrich Trick