Understanding 5G Mobile Networks

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Understanding 5G Mobile Networks: A Multidisciplinary Primer

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INVESTOR IN PEOPLE

This book is dedicated to Hilary Curwen who has endured much shouting at the computer

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List of Abbreviations

2G	Second generation
3G	Third generation
3GPP	Third Generation Partnership Project
4G	Fourth generation
5G	Fifth generation
6G	Sixth generation
APT	Asia-Pacific Telecommunity
AWRI	Advanced Wireless Research Initiative
BRS	Broadband Radio Services
CA	Carrier aggregation
CBN	China Broadcasting Network
CBRS	Citizens Broadband Radio Service
CIoT	Cellular IoT
CoMP	Co-ordinated multi point
DCC	Digital Communications Commission
D-MIMO	Distributed MIMO
DSS	Dynamic spectrum sharing
D2D	Device-to-device
EBS	Educational Broadband Service
EC-GSM-IoT	Extended coverage GSM IoT
eICIC	Enhanced inter-cell interference coordination
eMTC	Enhanced machine type communications
EU	European Union
FDD	Frequency division duplex
FTTP	Fibre to the premises

FWA	Fixed-wireless access
Gbps	Gigabits per second
GSM	Global System for Mobile Communications
GSA	Global Mobile Suppliers Association
HSPA	High-speed packet access
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
IMT	International Mobile Telecommunication
IoT	Internet of Things
ITU	International Telecommunication Union
LAA	Licence-assisted access
LBT	Listen before talk
LoRaWAN	LoRa wide-area network
LPWAN	Low-power wide-area network
LSA	Licensed shared access
LTE	Long term evolution
LTE-A	Long term evolution-Advanced
LTE-A Pro	Long term evolution-Advanced Pro
LTE-U	LTE in unlicensed spectrum
Mbps	Megabits per second
MEC	Multi-access edge computing
MIMO	Multiple input Multiple output
mmWave	Millimetre wave
mMTC	Massive machine type communications
MOCN	Multi-operator core network
MORAN	Multi-operator radio access network
MTC	Machine type communications
MU-MIMO	Multi-user MIMO
MVNE	Mobile virtual network enabler
MVNO	Mobile virtual network operator
M2M	Machine-to-machine
NB-IoT	Narrowband IoT
NB-LTE	Narrowband LTE

NFV	Network function virtualisation
NR	New radio
NSA	Non-standalone access
OFDM	Orthogonal frequency-division multiplexing
PAL	Priority access licence
PEA	Partial economic area
QAM	Quadrature amplitude moderation
RAN	Radio access network
RAT	Radio access technology
RSPG	Radio Spectrum Policy Group
SA	Standalone access
SDI	Software-defined infrastructure
SDL	Supplementary downlink
SDN	Software-defined networking
SEP	Standards essential patent
SIM	Subscriber identity module
SCRF	State Commission for Radio Frequencies
TDD	Time division duplex
TF	Technical Forum
TRAI	Telecom Regulatory Authority of India
UMB	Ultra mobile broadband
UMFUS	Upper microwave flexible use service
UMTS	Universal mobile telecommunications system
URLLC	Ultra-reliable and low latency communications
VHA	Vodafone Hutchison Australia
W-CDMA	Wide-band code division multiple access
WFA	Wi-Fi Alliance
Wi-Fi	Wireless Fidelity
WOAN	Wholesale open-access network
WRC	World Radiocommunication Conference

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List of Key Terms

5G
Licences
LTE
Mobile
Networks
Spectrum
Vendors

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About the Authors

Peter Curwen joined Sheffield Hallam University in 1970. He took early retirement in 2002 having risen to the position of Professor of Economics. Having switched his research interests from privatisation to telecommunications pre-retirement, he took up the post of Visiting Professor of Mobile Communications, first at Strathclyde University and subsequently at the Newcastle Business School, departing in 2017 to become a 'gentleman scholar'.

Jason Whalley joined Newcastle Business School in 2013 as Professor of Digital Economy, after a brief period as a consultant followed by more than a decade spent at Strathclyde University. His research focuses on the telecommunications industry, both fixed-wire and mobile. He has published extensively on the development of broadband markets, the Internet of Things and the use of ICT in the Himalayas.

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Preface

This book began life as a 5G database, compiled as a companion for those that had previously been compiled for both 3G and 4G and which had each evolved into a book (Curwen, 2002; Curwen & Whalley, 2013). However, in this case, the original idea had been to publish the 5G database in two separate articles covering country case studies because the need to analyse the technological aspects of 5G – far more extensive and complicated than those that needed to be explored and explained for 3G and 4G – appeared to be too problematic to combine with the country studies while restricting the content to the wordage permitted for articles.

In the event, it proved very frustrating to get the articles into print, especially as the country studies grew rapidly as time passed, so the decision was taken to investigate whether it would be practical to expand what had already been written into book form along the lines of Curwen and Whalley (2013). To achieve this, it would be necessary to add two other aspects of 5G to the existing country studies; firstly, a review of everything that had already been published about 5G and, secondly, a chapter (or two) exploring the technical underpinnings of 5G.

It rapidly became clear that whereas a number of highly technical books about 5G were already available – see, for example, Dahlman, Parkvall, and Skold (2020) and Osseiran et al. (2016) – these could only be properly understood by a reader with a scientific/engineering background. The other publications produced by non-academic sources consisted almost entirely of reports, some covering technical matters in reasonable detail, some concentrating upon country studies and some covering both but not in much detail. The only exception appeared to be Webb (2016) which was essentially polemical in nature.

So far as the academic literature was concerned, this tended to be fairly technical and often concerned with forecasting how 5G would affect things in the future – see Chapter 3. Given that 5G standards had yet to be fully agreed, this was a speculative activity at best.

What accordingly appeared to be wholly absent was any form of book that addressed the needs of non-specialist readers who nevertheless sought an insight into 5G either for professional reasons because they were studying telecommunications or were simply interested in something that they had been told would transform their lives.

In essence, compiling the country studies has been relatively straightforward, albeit time-consuming because there is always some disagreement between different sources as to matters such as dates that needs to be resolved. The main

problem has been how to deal with the technology. As noted in Chapter 1, 5G is part of a technological progression from 1G to 5G, and hence 5G cannot be treated independently of what has gone before. However, that essentially applies to so-called 'Non-Standalone' 5G which builds upon and coexists with the fourth generation of technology known as long term evolution (LTE). It is much less applicable to the independent strand of 5G which is commonly known as 'Standalone' – the distinction is clarified in Chapter 2.

For this reason, it became apparent to the authors that an initial understanding of 5G necessitated a prior understanding of LTE. Hence, a chapter would need to be devoted to explaining the development of LTE which was itself highly sophisticated – the modern smartphone that operates over LTE networks is to all intents and purposes a powerful mini-computer capable of processing data that has been downloaded at tens of megabits per second. A further chapter would then have to be added to cover the technological advances made during the past decade that have developed mobile technology well beyond the specifications of LTE and which underpin Standalone 5G.

This is not a straightforward matter because, as is evident from the above, there are two processes going on simultaneously. The first – which is what concerns the proverbial (wo)man on the omnibus – is essentially concerned with speeding up LTE in a world increasingly dominated by the need to download video (and to play sophisticated games). What (s)he wants is that massive video files, perhaps in the form of films, become downloadable within seconds rather than minutes without consuming too much of the data allowed within a standard mobile contract.

However, this process involves human participation whereas what is increasingly needed is to improve machine-to-machine (M2M) communication via what is generally known as the Internet of Things (IoT). The IoT is expected to connect up tens of billions of 'things', but without using the same transmission methods as those involving humans – for a start, there is nothing like enough licensed spectrum to meet the demands associated with the IoT. This means that new spectrum bands need to be exploited, largely in the absence of licences, and new technologies introduced to make this happen efficiently and economically.

For the purposes of this book, the major issue was not simply to introduce all of the relevant technology in a manner that would be understandable to readers, but to present it in a sensible sequence. The underlying principle has been that where the authors, who are not engineers, consider that they fully understand the basic principles underlying the technology it is presented as they understand it having checked multiple sources to avoid obvious errors. Anything that cannot be explained adequately in terms comprehensible to a non-engineer is outlined and extensively referenced, so readers can delve deeper if they wish.

The sequencing of material has been extremely problematic if only because the technology has not appeared in a series of finite steps. Rather, a substantial number of strands have developed over a lengthy period with multiple overlaps. The sequencing has been adjusted on numerous occasions during the drafting process, but it has to be admitted that there simply is no ideal way to do this.

So far as the country studies are concerned, the underlying principle has been to concentrate upon licence awards and launches. There are obviously large numbers of ongoing 5G trials at any given point in time, but to enumerate these would occupy far too much space. Furthermore, one of the key virtues of this book is that it provides a link between auctions and other forms of licence awards to network roll-outs and launches that have been achieved or are likely to occur during 2020. It should be added that the databases will be almost fully up-to-date at the time of publication, despite the time lag between manuscript submission and publication, as the coronavirus pandemic brought licence awards to a grinding halt in February 2020, and there was an associated disruption in the launch and dissemination of devices capable of handling 5G.

Finally, it is worth noting that because this book is, at least for the time being, unique, it is not going to be possible to assess how well the authors have met their objectives in comparison to other texts. All that can be said ultimately is that they hope that the book has achieved what it set out to do and that it will indeed prove to be useful to a wide range of readers.

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