

Making Everything Easier!TM

Sprint Business Special Edition

5G FOR **DUMMIES[®]**

A Wiley Brand

Learn to:

- Understand the innovations that are creating the 5G future
- Imagine new business models and opportunities
- Explore use cases that will transform entire industries — and everyday life

Brought to you by



Brian Underdahl

Foreword by John Saw, PhD



About Sprint Business

Sprint Business solutions make an impact on your business, helping you serve your customers better, more profitably, and more securely.

Our converged network is optimized to meet the demands of today's data-heavy, bandwidth-hungry business applications so you can do more, faster. We offer "as-a-service" solutions to help your business scale up or change course on a dime. Our flexible, BYO-ready approach fits the realities of today's workplace so your people can use the devices and carriers of their choice. And our Bend-over-Backward™ support gives your IT team their time back to focus on strategic projects. At Sprint Business, we serve as a trusted advisor, helping make your tech decisions simpler and better for your bottom line.

Sprint Business works for business.

5G

FOR

DUMMIES®

A Wiley Brand

Sprint Business Special Edition

5G

FOR

DUMMIES®

A Wiley Brand

Sprint Business Special Edition

by Brian Underdahl

DUMMIES®

A Wiley Brand

5G For Dummies®, Sprint Business Special Edition

Published by

John Wiley & Sons, Inc.
111 River St.
Hoboken, NJ 07030-5774
www.wiley.com

Copyright © 2018 by John Wiley & Sons, Inc., Hoboken, New Jersey

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the Publisher. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permissions>.

Trademarks: Wiley, For Dummies, the Dummies Man logo, Dummies.com, and related trade dress are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates in the United States and other countries, and may not be used without written permission. Sprint and the Sprint logo are trademarks or registered trademarks of Sprint. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc., is not associated with any product or vendor mentioned in this book.

LIMIT OF LIABILITY/DISCLAIMER OF WARRANTY: THE PUBLISHER AND THE AUTHOR MAKE NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS WORK AND SPECIFICALLY DISCLAIM ALL WARRANTIES, INCLUDING WITHOUT LIMITATION WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE. NO WARRANTY MAY BE CREATED OR EXTENDED BY SALES OR PROMOTIONAL MATERIALS. THE ADVICE AND STRATEGIES CONTAINED HEREIN MAY NOT BE SUITABLE FOR EVERY SITUATION. THIS WORK IS SOLD WITH THE UNDERSTANDING THAT THE PUBLISHER IS NOT ENGAGED IN RENDERING LEGAL, ACCOUNTING, OR OTHER PROFESSIONAL SERVICES. IF PROFESSIONAL ASSISTANCE IS REQUIRED, THE SERVICES OF A COMPETENT PROFESSIONAL PERSON SHOULD BE SOUGHT. NEITHER THE PUBLISHER NOR THE AUTHOR SHALL BE LIABLE FOR DAMAGES ARISING HEREFROM. THE FACT THAT AN ORGANIZATION OR WEBSITE IS REFERRED TO IN THIS WORK AS A CITATION AND/OR A POTENTIAL SOURCE OF FURTHER INFORMATION DOES NOT MEAN THAT THE AUTHOR OR THE PUBLISHER ENDORSES THE INFORMATION THE ORGANIZATION OR WEBSITE MAY PROVIDE OR RECOMMENDATIONS IT MAY MAKE. FURTHER, READERS SHOULD BE AWARE THAT INTERNET WEBSITES LISTED IN THIS WORK MAY HAVE CHANGED OR DISAPPEARED BETWEEN WHEN THIS WORK WAS WRITTEN AND WHEN IT IS READ.

For general information on our other products and services, or how to create a custom *For Dummies* book for your business or organization, please contact our Business Development Department in the U.S. at 877-409-4177, contact info@dummies.biz, or visit www.wiley.com/go/custompub. For information about licensing the *For Dummies* brand for products or services, contact BrandedRights&Licenses@Wiley.com.

ISBN 978-1-119-49269-6 (pbk), ISBN 978-1-119-49266-5 (ebk)

Manufactured in the United States of America

10 9 8 7 6 5 4 3 2 1

Publisher's Acknowledgments

We're proud of this book and of the people who worked on it. Some of the people who helped bring this book to market include the following:

Project Editor: Martin V. Minner

Editorial Manager: Rev Mengle

Senior Acquisitions Editor: Amy Fandrei

Business Development

Representative: Molly Daugherty

Production Editor: G. Vasanth Koilraj

Contents at a Glance

Foreword	ix
Introduction	1
Chapter 1: Introducing Wireless Network Evolution	3
Chapter 2: Understanding the 4G LTE Foundation for 5G	11
Chapter 3: When to Expect 5G: Standards and Timing	23
Chapter 4: Looking at 5G Networking	27
Chapter 5: Ten Great 5G Solutions	33

Table of Contents

Foreword	ix
Introduction	1
About This Book	1
How This Book Is Organized	2
Icons Used in This Book.....	2
Chapter 1: Introducing Wireless Network Evolution ..	3
Understanding the 3G, 4G Advanced/Pro, 5G Progression.....	3
3G	5
4G LTE	5
4G LTE Advanced.....	6
4G LTE Advanced Pro	6
5G.....	7
Understanding Spectrum	7
Considering Spectrum Types, Pluses, and Minuses.....	8
Low-band (< 2.5 GHz)	9
Mid-band (2.5-6 GHz).....	9
High-band (> 6 GHz)	10
Chapter 2: Understanding the 4G LTE Foundation for 5G	11
Providing Capacity.....	11
Spectrum drives capacity.....	12
MIMO	12
Beamforming	15
256QAM Modulation.....	16
Gaining Speed.....	16
Carrier aggregation.....	16
TDD versus FDD	17
Understanding Coverage Factors	18
Densification.....	19
Pole, strand, manhole	19
Accommodating Low-speed, Low-power IoT Devices.....	20

Chapter 3: When to Expect 5G: Standards and Timing	23
Considering the 5G Standards.....	23
International Telecommunications Union (ITU).....	24
3GPP	25
Understanding the Phases and Timing	25
Testing and Progress to Date	26
Chapter 4: Looking at 5G Networking	27
Understanding 5G Network Needs.....	27
5G New Radio	30
Evolving the Network Core.....	31
Network Function Virtualization (NFV)	31
Applying NFV/SDN to 5G.....	31
Chapter 5: Ten Great 5G Solutions	33
Augmented and Virtual Reality	33
Self-Driving Cars	34
Remote and Semi-Autonomous Robots.....	35
Monitoring and Repair Services.....	35
Power and Environmental Savings	36
Smart Cities for Enhanced Safety.....	36
Interconnected Transport Systems	37
Agriculture Sensors	37
Healthcare.....	38
Factories of the Future, or Industrial Automation.....	38

Foreword



Today's wireless networks are undeniably useful — with them you can book a flight, find your children, and video chat friends around the world. But these networks are just the beginning.

The next generation of wireless networks will offer entirely new levels of speed, low latency, and reliability. 5G will drive massive deployments of sensors paired with artificial intelligence that will spur new innovation across virtually all industries such as healthcare, offering not only data collection but patient monitoring and telemedicine. The extreme speeds and low latency of next generation networks can offer a tactile-capable world of virtual reality and augmented reality. Smart grids will automate energy systems, making them more dynamic and efficient. Autonomous vehicles and interconnected transport systems will dramatically improve road safety and fleet management.

At Sprint we see incredible opportunity for mobile 5G to leverage our foundation of 4G LTE and our spectrum, which includes the largest nationwide block of sub-6GHz 5G-capable mobile broadband spectrum in the United States. We're excited to help usher in the next generation of wireless networks that will drive new levels of innovation and progress around the world.

John Saw, PhD

Chief Technology Officer, Sprint

Introduction



Mobility and connectivity are two of the most important trends shaping the modern business climate. People and devices need reliable, ubiquitous, real-time connectivity in order to be productive and competitive in today's fast-paced world. The demand for faster, more dependable communication capabilities can only grow as time goes on, so you need to begin planning for the future if you don't want to be left behind.

5G, the next iteration of wireless networks, will enable significantly greater mobile speeds to enable real-time connectivity for mission-critical devices and applications. 5G networks will connect billions of Internet of Things (IoT) devices with a wide variety of speed and data volume requirements.

However, 5G is an ambitious goal. Work on key technologies to enable 5G has already begun. Initial 5G radio standards were defined in December 2017, with more 5G standards targeted for 2018. In much the same way that 4G technologies required a number of years of development to reach their full potential, 5G will be a steady evolution that begins with commercial availability expected in 2019. Many technologies that have emerged in the evolution of 4G LTE will continue to develop to achieve the massive speed and scale required in 5G.

Most carriers will likely start 5G in limited locations with hotspots or fixed wireless and will spread, just as 1G, 2G, 3G, and 4G did. However, Sprint will launch a mobile 5G network in first half of 2019.

About This Book

5G For Dummies, Sprint Business Special Edition, shows you what you need to know about the technological innovations that are being developed today to enable a 5G future. You also learn about potential use cases that will transform entire businesses and industries, as well as create new business models and opportunities.

How This Book Is Organized

Let's face it, you don't have a lot of time to waste. You want to get the information you need quickly so you can make a decision and get back to business. I understand that, so I've broken this book into several small chapters that get right to the point.

If you don't have time to read through everything right now, that's fine. Just jump to the chapter that seems to have the answers you need immediately. You can always come back later and pick up what you missed the first time (and I recommend that you do). But even if you skip around, don't miss the final chapter where you can find a bunch of important things 5G will offer.

Icons Used in This Book

This book uses the following icons to call your attention to information you may find helpful in particular ways.



The information marked by this icon is important and therefore labeled for emphasis. This way, you can easily spot noteworthy information when you refer to the book later.



This icon points out extra-helpful information.



This icon marks places where technical matters, such as jargon and whatnot, are discussed. Sorry, it can't be helped, but it's intended to be helpful.



Paragraphs marked with the Warning icon call attention to common pitfalls that you may encounter.

Chapter 1

Introducing Wireless Network Evolution

In This Chapter

- ▶ Looking at the progression of wireless
- ▶ Understanding the types of spectrum

As the name 5G (fifth generation) implies, the faster, more capable wireless network technology that companies like Sprint are developing is part of an evolutionary process. Over many years, mobile data networks have progressed from a tool that you could use occasionally into one that's become a vital part of everyday life. 5G wireless networks will enable possibilities well beyond what most people can imagine today.

This chapter shows you how wireless networking has evolved over the years. You'll see how 5G's greatly enhanced capabilities will enable it to serve many more purposes efficiently while delivering the performance to do things that seem like science fiction today. Hang on, it's going to be an exciting new world!

Understanding the 3G, 4G Advanced/Pro, 5G Progression

Years ago, mobile networks were designed for one use: voice communications. Before the advent of the smartphone, there wasn't much reason to think cell phones would ever need data services. The early mobile data services were so slow

and lacking in capacity that they made dial-up Internet access seem almost lightning fast.

Once the mobile carriers realized that there might be a market for mobile data, 2G (second-generation) data services were developed. In reality, though, 2G wasn't usable for many practical purposes. It took the development of 3G and later technologies like 4G LTE before wireless data became a usable, practical application. 5G, of course, is the next step in the evolution of the modern wireless network.

Figure 1-1 looks at the evolution of these generations of technologies. The following sections provide additional detail on the progression through the generations.

Phase	3G	4G LTE	4G LTE Advanced	4G LTE Advanced Pro	5G
Standards defined	2000's	2010	2011-2014	2017	2018+
Peak data speeds	2 Mbps	150 Mbps	< 1 Gbps	>1 Gbps	>2 Gbps
Key technologies					
Carrier aggregation			✓	✓	✓
Advanced MIMO			✓	✓	✓
Massive MIMO				✓	✓
256 QAM			✓	✓	✓
Cat M and NB IoT				✓	
5G New Radio					✓
Network Needs	Low speed data	Faster speeds	Faster speeds	Faster speeds, higher capacity	Network flexibility, reliability, latency
New services introduced	Voice, email, web, location	Streaming audio	Streaming video	HD video	Virtual and augmented reality, AI

Figure 1-1: Seeing how mobile data has evolved over generations.

3G

The first modern smartphones appeared around the year 2006 (about a year before Apple's iPhone was introduced). People soon realized that a smartphone could do many wonderful things, but that many useful functions, such as accessing the Internet, required faster wireless data access. This realization drove demand for improved data services, and the manufacturers and carriers responded with 3G (third-generation) devices and networks.



Developing new generations of wireless network devices and services takes years of work and testing. Just as companies like Sprint are working on 5G several years before the service will become available, each of the earlier generations was in development for quite some time before it was ready for daily use by consumers.

At about 2 Mbps (megabits per second), 3G wasn't exactly broadband, but it certainly beat the existing dial-up era speeds that were previously available. With 3G devices and services, mobile devices could now provide voice, email, web browsing, and location services that weren't practical before.



Wireless network speeds are typically quoted as the maximum theoretical performance that can occur under optimal conditions. In the real world, you can expect to see lower actual speeds, but you'll likely see gains that conform fairly well to the ratios between the theoretical performances of the different standards. Of course, you'll need devices compatible with the newer standards in order to take advantage of that additional performance. In addition, if you're in an area with a less than optimal signal, you may find that your effective speed is reduced or even degraded to use an earlier generation network.

4G LTE

With the rising popularity of smartphones, carriers realized that the demand existed for higher-speed wireless communications services. In 2010, 4G LTE was introduced to meet this demand.



Long-Term Evolution (LTE) is a standard that was developed for high-speed wireless communications and was the first to use Orthogonal Frequency Division Multiplexing (OFDM), which reduced interference and improved signal reliability. LTE simplified the network architecture using an IP-based system. LTE is incompatible with 2G and 3G networks, so it requires a separate radio spectrum and LTE-compatible devices.

Offering up to 150 Mbps, 4G LTE was much faster than 3G, so users were able to stream audio as well as use other dynamic services. This capability meant that streaming audio such as Pandora and podcasts became practical for mobile users.

4G LTE Advanced

Standards for 4G LTE Advanced were introduced in 2011. This new form of 4G LTE would not only increase capacity but also support speeds up to 300 Mbps, so users could stream video from sources such as YouTube. The world of cat videos has never been the same. Several new technologies were also added to the standard in 2013, which would increase peak speeds significantly to 1Gbps. Keep in mind that the dates reflect when the standards were defined. Many of these technologies are just now being deployed in wireless networks as well as the latest versions of smartphones and devices.



4G LTE Advanced used *carrier aggregation*, a technique that combined multiple frequencies and multiple-input multiple-output (MIMO) features. Effectively, 4G LTE Advanced enabled data to travel on multiple pipes at the same time for greater throughput.

4G LTE Advanced Pro

Technology continues to advance all the time, so by 2017 people no longer were satisfied with just seeing cat videos on YouTube. Now they wanted those videos to be in high definition (HD).

With the evolving use of video and introduction of unlimited data plans putting ever-increasing demands on wireless networks, new ways of increasing capacity in the network became important. A new technology called Full Dimension Massive

MIMO was introduced in the LTE Advanced Pro standard in 2017. You will see Sprint deploying this technology in 2018.

In addition to introducing new technology to increase capacity, LTE Advanced Pro introduced new standards for low-speed, low-power network capabilities and devices used in the Internet of Things (IoT). You can read more about this in Chapter 2.

5G

The industry continues looking to the future as the uses and demands for mobile data keep expanding. 5G, which will begin in 2019 and continue to grow for years beyond, is being designed to provide speeds higher than 2 Gbps while offering improved capacity, scale, latency, and reliability.



Latency is the lag or delay between when data is sent and when it is received. Gamers often complain about latency because in a fast-paced game, any delay between when you try to take an action and when the action actually happens can mean the difference between winning and losing. However, latency isn't an issue only for gamers. Virtual and augmented reality applications require very low latency to avoid nausea-inducing delays when someone using the application turns his or her head. But low latency becomes absolutely essential for critical control in certain situations such as autonomous vehicles.



As was the case with earlier steps along the way to faster mobile data, 5G will require new hardware at the network and device level that's compatible with the 5G New Radio (NR) standards. You'll want to plan for the new capabilities and be ready to upgrade so you can take advantage of all 5G will offer.

Understanding Spectrum

Having enough spectrum has always been one of the biggest challenges in the wireless industry. A large percentage of the low-band, easy-to-use frequencies were allocated to other purposes such as broadcast radio, television, and public safety years ago.

Another way to think about spectrum is a highway. The amount of spectrum you have determines how many lanes your highway has. With more data (cars on your highway), the more lanes (spectrum) the better.



The bandwidth that's available within a spectrum band greatly determines how much network performance is available to users. In low-band spectrum, bandwidth is typically limited, so data rates tend to be low. In mid-band and high-band spectrum, the available bandwidth can be many times greater than what's available in low-band. As a result data rates can be higher.

Spectrum can be *licensed* or *unlicensed*:

- ✓ **Licensed spectrum** consists of a band of frequencies that a carrier has been given authorization to use by a government licensing agency such as the Federal Communications Commission (FCC). Licensed spectrum is usually reserved for the exclusive use of the licensee, and the right to license a band is often purchased in what's known as a *spectrum auction*. A band of frequencies may be divided up so that there are multiple licensees, each with its own set of frequencies. Licensed spectrum usually allows a better user experience because the operator can better manage the use of the spectrum and will be less likely to experience interference.
- ✓ **Unlicensed spectrum** contains bands of frequencies that are available for anyone to use. For example, Wi-Fi networks and microwave ovens operate in a band of unlicensed spectrum in the 2.4 GHz range. Unlicensed spectrum has the advantage of being free to use, but because no one has an exclusive right to the spectrum, interference between users can sometimes be a problem.

Considering Spectrum Types, Pluses, and Minuses

To meet evolving needs, 5G is designed to utilize an expanded range of spectrum between 600 MHz and 100 GHz. Of course, it's important to pair the spectrum with the intended task.

Figure 1-2 illustrates the relationship between frequency and wavelength. This relationship has a profound effect on the suitability of those frequencies for different purposes.

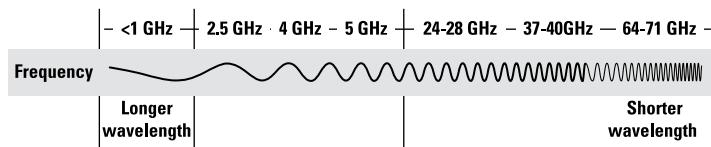


Figure 1-2: As frequency increases, wavelength decreases.

The next few sections look at some of the spectrum that 5G systems will use.

Low-band (< 2.5 GHz)

Low-band spectrum consists of frequencies below 2.5 GHz. This spectrum offers the advantage of wide-area coverage and also the ability to penetrate buildings so that devices can function reliably in many indoor areas.

Unfortunately, low-band spectrum also has some disadvantages, notable among them being limited bandwidths available, which leads to lower data rates and congestion. Many of the frequencies below 2.5 GHz have already been allocated to other uses such as television broadcasts, other wireless deployments, and public safety.

Mid-band (2.5-6 GHz)

Spectrum between 2.5 Ghz and 6 GHz offers greater capacity and speed than low-band spectrum provides. In addition, this spectrum is less congested and has many more frequencies available for carrier use.

Mid-band spectrum has somewhat shorter range and is more easily blocked by solid structures, so cell towers must be spaced closer together in order to provide area-wide coverage. Indoor coverage often requires some type of enhanced coverage solution.

High-band ($> 6 \text{ GHz}$)

In some 5G solutions, the range of frequencies above 6 GHz becomes more useful. This high-band spectrum offers extreme capacity and speed.

High-band spectrum has extremely short range (perhaps just a few hundred meters) and is currently practical only for fixed or very limited mobility uses. This spectrum requires massive densification because of its short range.

5G challenges some of the nomenclature that's traditionally used for spectrum. *Low-band*, *mid-band*, and *high-band* for 5G mean something entirely different from what they mean in current 3G/4G networks. Frequencies considered high-band for 4G, such as 2.5 GHz, are in reality mid-band for 5G when you consider that most new 5G bands use much higher frequencies.



Although mid-band and high-band spectrum have reduced range, the higher frequencies involved mean that antennas can be smaller in size.



Key technologies like massive MIMO are extremely challenging to support with spectrum below 1 GHz because of the size of the antennas. With frequencies in the mid-band and high-band range, antennas become much smaller, so more antennas can fit into the same space that was used by lower bands. This characteristic plays an important role in massive MIMO and the multifold increase in capacity it provides.

Many frequencies currently used in mobile networks can be used for 5G (in a process called *refarming*). Sprint has a plan using massive MIMO that will use the same 2.5 GHz of spectrum for 4G LTE and 5G. As 5G devices become more common, there will be less demand for 3G and 4G services, which will allow these bands to eventually be dedicated for 5G use.

Chapter 2

Understanding the 4G LTE Foundation for 5G

In This Chapter

- ▶ Seeing how 4G LTE increases capacity
 - ▶ Understanding how 4G LTE boosts speed
 - ▶ Looking at what influences coverage
 - ▶ Accommodating Internet of Things devices
-

Something as transforming and massive as 5G doesn't just happen on its own. Planning and achieving such an important transition takes forward thinking and building a solid foundation.

This chapter shows you how companies like Sprint are laying the foundation for 5G. You'll see how technologies such as carrier aggregation, MIMO, beamforming, advanced modulation techniques, UE Relay, beamforming, and others are being developed and advanced to provide the 5G services you'll depend on in the future.

Providing Capacity

Most people give little, if any, thought to network capacity. Even so, it's vital that the wireless network have enough capacity to handle today's demands as well as to meet future needs that haven't even been dreamed up yet. Consider that on-demand streaming video services like Netflix and Amazon Prime Video didn't exist just a few short years ago. If you wanted to watch a movie, you likely drove to your local Blockbuster video store and rented a DVD. At the time, having

a video store probably seemed like a good, long-term business plan. Today, most video stores no longer exist because network capacity has made it possible to simply stream or download a movie.

Spectrum drives capacity

If you've tried streaming a 4K movie over a wireless network connection, you've probably encountered an on-screen spinning disk or other message indicating that the movie was buffering. Quite simply, existing wireless networks often struggle with insufficient capacity to handle modern demands such as streaming 4K content due to lack of spectrum. In part, this lack of capacity stems from the relatively low frequencies used by existing networks.

As mentioned in Chapter 1, 5G will use higher frequencies and technologies like MIMO, higher-order carrier aggregation, and 256 QAM “quadrature amplitude modulation” to allow you to watch ultra-high definition content without being bothered by that annoying little spinning disk in the center of your screen. Figure 2-1 shows how higher-frequency shorter wavelength spectrum is used to increase capacity.

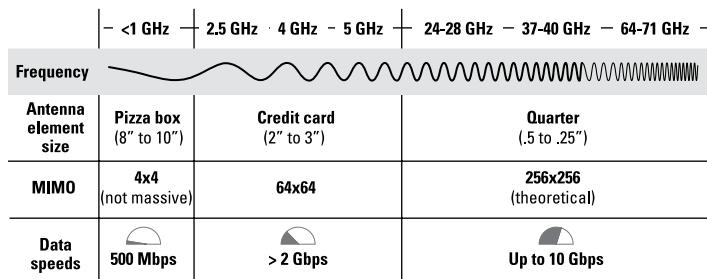


Figure 2-1: The higher frequencies used by 5G will enable greater capacity.

MIMO

In addition to using a much broader range of frequencies, capacity can be increased by using more radios at higher frequencies where antenna sizes are much smaller. In the previous example of spectrum being the width of a highway, think of MIMO as the ability to add layers to your highway. Imagine

a double- or triple-decker highway with MIMO, and even more with massive MIMO. With the right spectrum, wireless network providers can add many layers, thus increasing the capacity of the network manifold.

Communication systems are classified based on how many transmitters and receivers they have:

- ✓ **SISO (Single Input Single Output)** systems have one transmit and one receive branch (1T1R).
- ✓ **MIMO (Multiple Input Multiple Output)** systems have more than one transmit branch and more than one receive branch (2T2R, 2T4R, 4T4R, 8T8R, and so on).
- ✓ **Full Dimension Massive MIMO** systems have tens or hundreds of transmit and receive branches (64T64R, 128T128R, and so on). These additional antenna elements greatly increase capacity and provide carriers the ability to aim the signal in three dimensions.

The capabilities of a massive MIMO system are determined by the frequency of operation. The element size of an antenna is dictated by the wavelength of the signal the antenna is built to transmit or receive. Higher frequency bands have smaller wavelengths and vice versa. Because a large number of antenna elements are required for building high-performance massive MIMO systems, higher frequency bands (~2 GHz or higher) are better suited for the task. Figure 2-2 shows Sprint's 64T64R Massive MIMO antenna system.

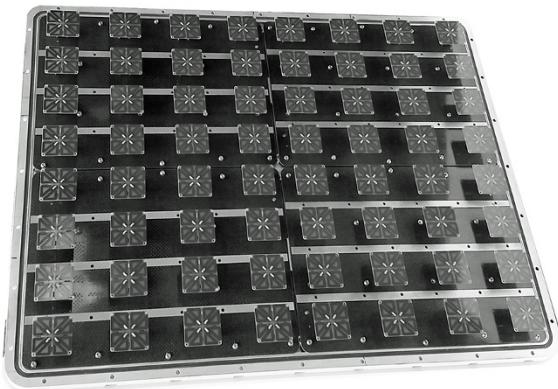


Figure 2-2: Sprint's 64T64R massive MIMO antenna system.



A MIMO layer can be thought of as a dedicated data stream. More MIMO layers result in more throughput. Current LTE systems support 8-layer MIMO. Massive MIMO systems can support 8 or 16 layers currently and will support a higher number of layers (24 or more) in the future.

There are also different types of MIMO:

- ✓ **Single-user MIMO (SU-MIMO)** is where multiple streams using multiple antennas are directed to a single device.
- ✓ **Multi-user MIMO (MU-MIMO)** is where multiple streams using multiple antennas are directed to many devices.

Figure 2-3 provides an example of a massive MIMO system, which will be one of the key elements of 5G deployment.

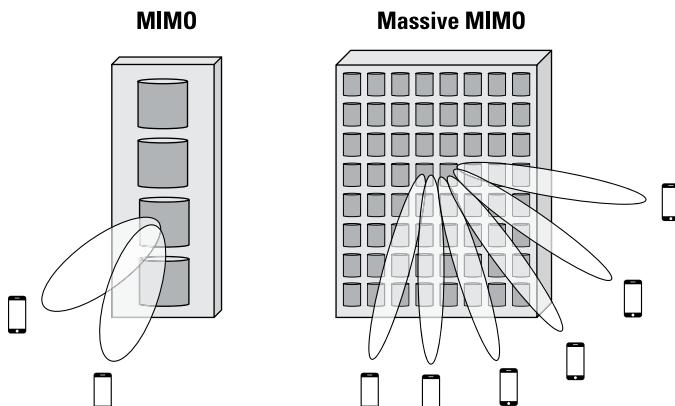


Figure 2-3: Massive MIMO systems will provide large-capacity gains.



With their large number of antenna branches, advanced beam-forming capabilities, support for higher MIMO layers, and multi-user MIMO, massive MIMO systems improve both coverage and capacity in ways that no prior LTE feature has.



A smaller wavelength means less captured energy in an antenna. A larger number of antenna elements will be needed in the antenna array to achieve the required array gain.

Given that many 5G deployments will be in higher bands, 5G radios are expected to be massive MIMO systems.

Beamforming

Beamforming is the technique of focusing the signal to the intended recipient while minimizing noise (such as signals meant for other users). Beamforming techniques vary from simple analog beamforming (where you orient the entire sector coverage area to where it's needed) to more sophisticated digital beamforming where device-specific beams can be created.



Early implementations included only horizontal plane beamforming. Later advanced implementations use 3D beamforming — employing both elevation (vertical) and horizontal (azimuth) — to help steer the user-specific beams precisely in the 3D space. This technique is useful when users are both on the ground and inside buildings on different levels.

The key benefits of beamforming are improved coverage for cell-edge users and reducing overall interference. In more advanced implementations, the added benefit of reusing the same time-frequency resources among different spatially separated users (multi-user MIMO) can also be seen.



Adaptive antenna systems with a large number of elements and arrays are needed for creating effective user-specific beams. 3D Beamforming is enabled by advanced radio technologies such as massive MIMO.

Figure 2-4 shows how beamforming can direct signals exactly where they're needed.

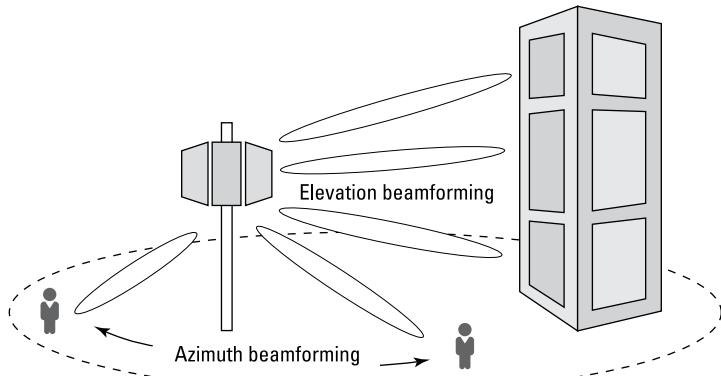


Figure 2-4: Using beamforming to direct signals.

256QAM Modulation

Higher data rates also help to improve network capacity. Quadrature amplitude modulation (QAM) is a technique used to enable higher data rates.



Modulation is the process of embedding data to be transmitted over radio frequency (RF). Various modulation techniques are in use, each with its own merits and demerits. Within the various QAM schemes, increasing numbers (order) mean that more data bits can be packed with fewer symbols. For example, 16QAM (4 bits per symbol) has less capacity than 64 QAM (6 bits per symbol), which has less capacity than 256 QAM (8 bits per symbol). Increasing order provides higher throughputs with the same amount of carrier RF.

The quality of the signal, often represented as a signal-to-noise ratio (SNR), determines which modulation scheme can be used effectively. The signal quality needed for 256 QAM is greater than 64 QAM, and as you move farther away from the cell site the signal quality declines, and you may step down from 256 QAM to 64 QAM.



Think of modulation as the amount of cargo (or data) each truck on a highway can carry. With 16QAM you can carry four boxes per truck, but with 256QAM you can carry eight boxes in the same truck. That is double the capacity of each truck, which is a huge improvement in speed and capacity.

Gaining Speed

Another promise of 5G is much higher data speeds. 5G is designed to incorporate a number of technologies that will enable you to do things like download an entire HD movie in a couple of minutes while you're waiting to board a flight. Imagine, no more having to put up with a talkative seatmate who insists on sharing the intimate details of his hobby growing heirloom rutabagas!

Carrier aggregation

Carrier aggregation (CA) is a technique of combining multiple data streams to improve throughput. CA can aggregate multiple LTE component carriers (CCs) to achieve high-bandwidth

transmission, and is supported in both downlink (DL) and uplink (UL). The 3rd Generation Partnership Project (3GPP) standards allow CA for up to 32 CCs on downlink in LTE-Advanced Pro.

Think of carrier aggregation as the ability to take spectrum and combine it into a superhighway. The more spectrum you have, the more carriers you can combine, and the wider the superhighway can be.

Figure 2-5 illustrates how carrier aggregation combines multiple component carriers to provide greatly enhanced throughput.

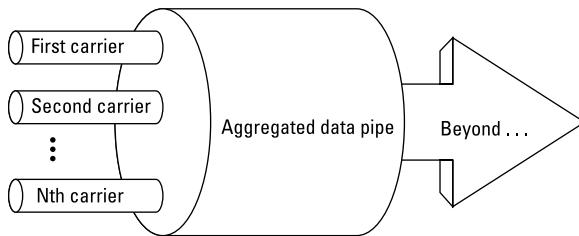


Figure 2-5: Carrier aggregation combines multiple data streams.

TDD versus FDD

Duplexing technologies enable two-way communications by providing paths for both uplink and downlink traffic. Modern mobile communication systems use one of two duplexing schemes, *Frequency Division Duplexing (FDD)* or *Time Division Duplexing (TDD)*.

Here's a look at how FDD and TDD compare:

- ✓ FDD networks use dedicated spectrum for uplink (UL) and downlink (DL) operations.
- ✓ The amount of uplink and downlink spectrum is normally equal in FDD (but is not a requirement).
- ✓ Common usage patterns show data is asymmetric (down-link heavy).
- ✓ Dedicating equal amounts of spectrum in both directions leads to under-utilization of spectrum in FDD.

- ✓ Unlike FDD networks, TDD networks can use the entirety of the spectrum for uplink or downlink (but can only transmit or receive at a point in time; unlike FDD networks, where simultaneous transmission and reception are possible). In TDD, the uplink and downlink take turns. This all happens transparently to the end-user because it takes just milliseconds.
- ✓ TDD offers flexibility in allocating resources between uplink and downlink.

TDD is also better suited for massive MIMO systems, compared to FDD. One of the fundamental characteristics of TDD is the flexibility it will offer in deployments and efficient spectrum utilization.

Understanding Coverage Factors

In addition to capacity and speed, another factor is very important in determining how usable any wireless network may be. That factor is coverage, because if you can't get a signal, the potential capacity and speed are meaningless.

As mentioned previously, 5G wireless networks will use a much broader range of frequencies than were utilized in earlier networks. However, this broad range of frequencies adds a complication: Although higher frequencies can deliver much higher bandwidth and data rates, higher frequency radio waves can be effectively used only over much shorter distances. Figure 2-6 shows how increasing the frequency decreases the typical propagation range. Note that for the purposes of this discussion, I'm using the 5G definitions of spectrum bands discussed in Chapter 1.

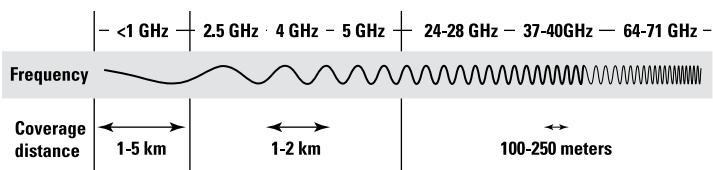


Figure 2-6: Higher frequencies result in shorter ranges.

Carriers use a number of solutions to deal with the shorter range of higher-frequency spectrum.

Densification

Densification is adding more cell sites to an area. Network densification is inevitable to keep pace with the growing number of devices and increasing demand for data. When more cell sites exist in an area, users likely will be closer to one of those sites, so coverage and capacity become less of a problem.

Deployment of large numbers of small cells with lower power is a cost-effective solution for network densification. These small cells can be deployed either at the cell boundary of macro cells (both indoor and outdoor) to fill the coverage holes, or under the coverage of macro cells to increase system capacity and offload traffic from macro cells. In this heterogeneous or multi-layered network deployment, the small cell layer can be deployed anywhere needed as a complement of the macro cell layer to increase capacity and data rate.



A large scale deployment of small cells must be facilitated by self-organization networks (SON) and inter-cell interference management. Full benefits of network densification can be realized only if it is complemented by increased back-haul. There is a growing need for wireless/in-band backhaul because it is getting increasingly harder to deploy wired back-haul in urban centers where it's needed the most.

Figure 2-7 shows how densification works.

Pole, strand, manhole

You don't have to worry that densification means that you're going to see a bunch of giant, ugly cell towers proliferating in your neighborhood. In fact, because of the extremely short wavelengths of the mid-to-higher frequency spectrum that will be used, the antennas will be so small that you may not even notice them.

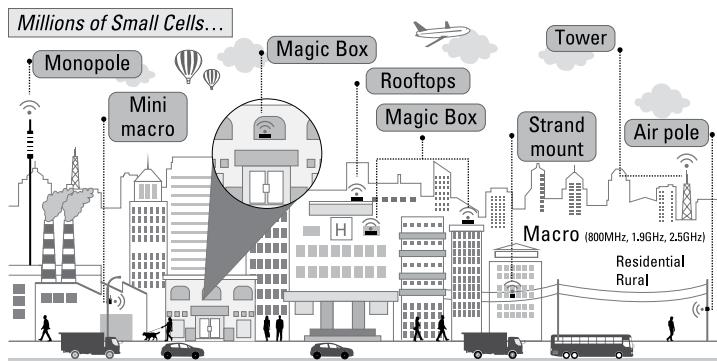


Figure 2-7: Densification adds lots of little cell sites in an area.

With extremely high frequencies, antennas can be easily hidden because of their small size. For example, an antenna might be a single small pole, a strand, or even a manhole cover. In any case, the small cells will be tiny and virtually unnoticeable.

Accommodating Low-speed, Low-power IoT Devices

There's little doubt that the Internet of Things (IoT) is a hot topic. Developers are adding intelligence and connectivity to all sorts of things, from connected garage door openers to remote weather stations and even refrigerators that can send you a message to remind you to pick up milk and eggs on your way home from the office.

Just as important as faster speeds are to smartphones and video, very low-speed, low-cost devices are to IoT applications such as remote monitoring sensors. An increasing trend with IoT devices is to make them as low-cost and low-power as possible. Often, these devices are battery powered and may be located in places where replacing batteries or performing other service can be inconvenient.

Evolving IoT networks are being designed to accommodate these devices through several new technologies shown in Figure 2-8.

	LTE CAT-1	LTE-M1 Rel 13	LTE-M2 Rel 14	NB1-IoT Rel 14	NB2-IoT Rel 14
Bandwidth	20 MHz	1.5 MHz	1.5 MHz	200 kHz	200 kHz
Data rate	10 Mbps	375 kbps	1.5 Mbps	65 kbps	150 kpbs
Current (idle mode)	1-2 ma	<15 ua	<15 ua	<15 ua	<15 ua

Less bandwidth, lower speed, lower power →

Figure 2-8: New IoT network technologies.

Chapter 3

When to Expect 5G: Standards and Timing

In This Chapter

- ▶ Understanding the 5G standards
 - ▶ Seeing when 5G will arrive
 - ▶ Looking at testing and progress to date
-

The rollout of 5G is going to be transformational. Not only will wireless networks have more capacity and higher speed, but the proliferation of Internet of Things (IoT) and other devices supported by the 5G network will result in new products and services that haven't even been imagined.

This chapter discusses what must happen in order for 5G to reach the marketplace. You'll see why global agreement on standards is so vital, as well as how proper testing will help ensure that 5G is ready when it is deployed.

Considering the 5G Standards

Standards play an important role in making sure that products and services from different companies are compatible. It's pretty obvious that standards are necessary. Imagine the chaos that would result if each device manufacturer and each wireless service provider decided to develop its own systems without regard for interoperability with other companies' equipment. You'd be locked into a little closed garden where you could get equipment from only one vendor, and service from only one supplier. With no competition, the vendors

could charge you as much as they like. Fortunately, manufacturers have agreed that it's important to make equipment that's compatible with established standards so that equipment from different manufacturers can function together. In fact, three organizations are working to make sure that telecommunications equipment used in the United States meets certain standards so that equipment can be interoperable.

International Telecommunications Union (ITU)

The ITU sets performance goals as well as spectrum global policy and guidelines. The ITU is an agency of the United Nations (UN) whose purpose is to coordinate telecommunication operations and services throughout the world. Originally founded in 1865, as the International Telegraph Union, the ITU is the oldest existing international organization dealing with telecommunications standards. You can find out more about the ITU at www.itu.int.

The ITU plays a leading role in the work on 5G standards. In many countries, companies can only deploy technologies endorsed by ITU, and some countries can only deploy specific technologies in certain bands based on what technology the band was allocated for. Although the United States does not require compliance with the ITU standards, American carriers realize the importance of these standards.

5G has been a marketing name given to the requirements and performance expected from the ITU recommendations for IMT-2020 systems. Improved Mobile Telecommunications (IMT) is a family of requirements that started with the 3G requirements. IMT Advanced is the name for the 4G requirements, and now IMT-2020 is officially called 5G.

Starting back in 2012 the ITU started a project on "IMT for 2020 and beyond." The details of this project are available online at www.itu.int.

3GPP

The ultimate standards body, the 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations and provides their members with an environment to produce the reports and specifications that define 3GPP technologies. In addition to those mentioned so far, you can find additional information at the 3GPP website: www.3gpp.org.

Understanding the Phases and Timing

Just like the testing and rollout of 4G services over the past decade, 5G testing and rollout will take place over several phases. Each of these is intended to ensure that problems are discovered early enough so that they can be rectified as the testing continues. These phases will also introduce new capabilities that will enable new 5G solutions.

A key technology defining 5G will be the introduction of 5G New Radio. The requirements are expected to be released by 3GPP over three phases.

Figure 3-1 illustrates the expected phases and timing of the testing and deployment of 5G technologies.

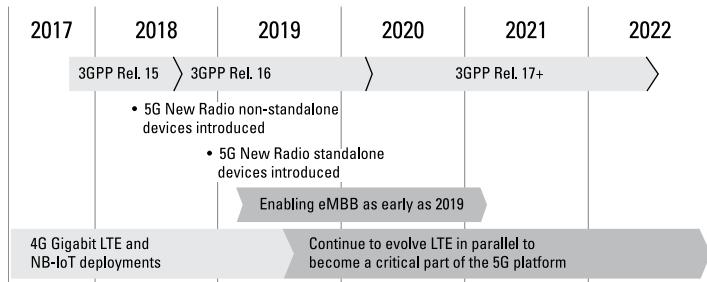


Figure 3-1: Testing and deployment of 5G NR is expected to take several years.

Testing and Progress to Date

As a part of the development leading up to 5G, carriers have been testing several of the technologies that will be used. Here are some of the highlights of what has been done so far and what's in the pipeline:

- ✓ In June of 2016 Sprint demonstrated 5G at COPA. See www.rcrwireless.com/20160614/carriers/sprint-5g-demo-set-philly-part-copa-america-centenario-tag2.
- ✓ Sprint was the first U.S. carrier to deploy gigabit class LTE on a commercial network on March 9, 2017. See <http://newsroom.sprint.com/sprint-debuts-gigabit-class-lte-in-new-orleans.htm>.
- ✓ In 2017, AT&T began customer trials in the 39 GHz spectrum band.
- ✓ Verizon began customer trials in the 28 GHz spectrum during 2017.
- ✓ Sprint trialed massive MIMO in Seattle in Aug of 2017. See <https://www.youtube.com/watch?v=08iAYPxcClk>.
- ✓ Leveraging 2.5GHz, Sprint is starting massive MIMO deployment in large scale in 2018, which will enable nationwide 5G deployment in 2019.

Chapter 4

Looking at 5G Networking

In This Chapter

- ▶ Understanding the new technology
 - ▶ Grasping the breadth of 5G solutions
-

5G promises to bring about huge changes in the way people think about and use wireless communications services. Things that are extremely difficult or impossible today will become commonplace. Virtually instantaneous movie downloads, greatly increased capacity and safety on the roads resulting from self-driving cars, and ubiquitous virtual assistants built into ordinary everyday devices will make life simpler, safer, and more enjoyable.

This chapter looks at the capabilities that new 5G solutions will require of the network and the key technologies that enable them.

Understanding 5G Network Needs

The 5G network will be required to service many different requirements. For example, many Internet of Things (IoT) devices will use low-power, low-speed connections to enhance battery life. On the other hand, as self-driving vehicles become common, they'll have an absolute need for virtually instantaneous network response to avoid creating dangerous conditions. The 5G network will have to be tailored to the specific requirements of a wide variety of uses. Figure 4-1 illustrates some of this variety.

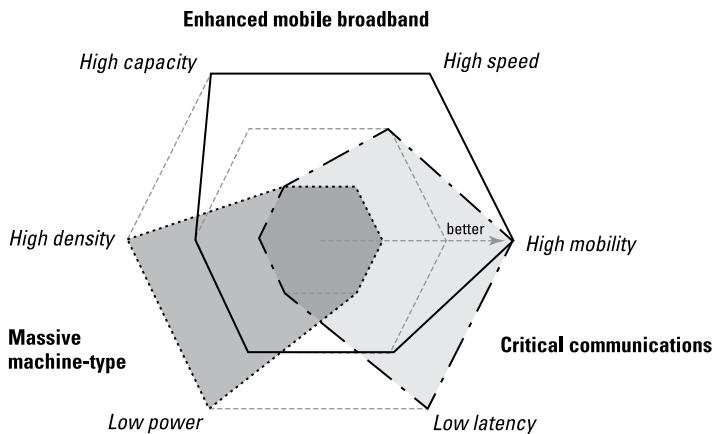


Figure 4-1: Different uses will place unique sets of demands on the 5G network.

Here are the categories that will define future 5G solutions:

- ✓ **Enhanced mobile broadband (eMBB):** Uses such as virtual reality (VR) and augmented reality (AR) demand a lot from the network in data speed and mobility. It's absolutely vital that a user wearing a VR or AR headset have a visual experience that corresponds correctly to the real world, because otherwise users would quickly become disoriented and might even feel nauseated. You shouldn't dismiss these technologies as just something for gamers, either. Devices such as the Microsoft HoloLens show great promise in enabling things like showing field technicians how to make repairs to complicated machinery safely and quickly.
- ✓ **Massive machine-type communication (mMTC):** Uses such as monitoring and repair services, power and environmental savings, smart cities for enhanced safety, interconnected transportation, agriculture sensors, and healthcare will create a demand for the network to handle immense numbers of connections within dense environments. In addition, because many of these devices will operate on batteries, power consumption will be a big driver toward extremely efficient power usage.

- ✓ **Critical communications (CriC):** Uses such as self-driving cars, remote robotics, and semi-autonomous robotics have a vital need for extremely low latency and mobility. For these devices to operate safely, there can't be any unnecessary delays and the connection must be extremely reliable. For example, Airbus has said it wants to build a fleet of electric, autonomous, multi-rotor VTOL aircraft called the Vahana that can be used to fly within cities. You wouldn't want such vehicles flying overhead without an ultra-reliable, low latency network connection helping keep some order in the skies! See www.theverge.com/2017/11/13/16633392/airbus-vahana-flying-car-a-cubed-photos.

Technological advances always bring changes to people's lives. The automobile enabled people to travel farther and faster than ever before. Radio made it possible for people to get instantaneous news and entertainment. The Internet enabled companies like Amazon to completely reshape the retail shopping experience. The smartphone changed telephones into personal communications devices that today are most often used for purposes other than speaking to another person. Just as these earlier technological advances changed many aspects of modern life, 5G will bring about many changes as a result of new capabilities such as:

- ✓ **Much greater speed:** 5G will provide peak network speeds of up to 2 Gbps. With 5G, you could theoretically download a 4K ultra-high-definition movie in just a few minutes. With this level of network performance, imagine how things like real-time, multiplayer, virtual reality gaming will change. Who knows what other new ideas will spring from having such speed at your fingertips?
- ✓ **Huge scale:** 5G will have capacity to deal with the billions of IoT devices that will be connected to the Internet in the next few years. Such huge capacity will enable almost everything to gain smart capabilities, increasing convenience and safety for everyone.
- ✓ **Extreme responsiveness:** Certain tasks absolutely require ultra-low latency to ensure positive outcomes and the safety of everyone involved. 5G networks will

offer the ultra-low latency demanded for these critical tasks. For example, it may be possible to develop portable microscopic surgery machines that can be operated via telemedicine so that delicate surgery may be performed in rural clinics without the need to transport patients to big-city hospitals. Or, the ultra-low latency may make it possible for convoys of autonomous trucks to safely travel at high speed a few feet apart, thus greatly reducing fuel consumption.

The next section offers a closer look at some of the specific technologies that 5G will use to provide these benefits.

5G New Radio

5G New Radio is the term used to describe the radio technology being developed to support the new features of 5G. This technology will be programmable, flexible, and capable of being adapted to a number of purposes. Some of the key features of 5G New Radio will include:

- ✓ **Expanded frequency range:** 5G New Radio will use frequencies (spectrum) well beyond the range of most current wireless technology.
- ✓ **Scalable OFDM:** This allows wireless network providers to more easily scale carrier bandwidth and support diverse spectrum.
- ✓ **Massive MIMO:** This enables efficient utilization of a large number of antennas to increase coverage and capacity. The 5G NR, with support of TDD-based multi-user massive MIMO and 3D beamforming enable significant gains in both capacity and cell edge performance. These improvements enable a more uniform 5G mobile broadband user experience.
- ✓ **Flexible slot-based architecture:** This is a key component of the 5G New Radio that will enable significantly lower latency than LTE. It will also enable more adaptive flexibility in allocating uplink and downlink capacity as well as enhanced efficiency of massive MIMO systems as compared with LTE massive MIMO systems.

Evolving the Network Core

Moving from 3G/4G to 5G requires some major planning and rework of the core network that underpins the whole wireless communications system.

Network Function Virtualization (NFV)

Because the 5G network is intended to support many additional types of uses, providers have to move away from rigid, hardware-defined systems into something that's more flexible and adaptable. These types of changes are possible only by making the network more software-centric. This is similar to using a software-driven virtual machine (VM) to run a Windows operating system on a Mac OS personal computer.

On the core network side, service-based architecture (SBA) is being introduced as part of the 5G core architecture, in which the network functions (NF) components now support a set of NF services and operations that are defined in the architecture. Software-defined networking (SDN) is an essential element in this process.

Applying NFV/SDN to 5G

In 5G, NF services must be self-contained, must scale independently, and must allow independent software upgrades without affecting other NF services. The underlying technology for the network functions are based on SDN/NFV technologies.

In addition to NFV, the 5G network will use *network slicing*. Network slicing is an end-to-end architecture that is logically separated, or *sliced* to support the needs of the different industry segments or service categories. It allows a collection of network and application functions to be grouped together logically to support different categories of services. Each network slice draws from a common pool of physical and logical resources but is independent and can support customized service behavior or service SLAs.

Different network slices can be constructed from some common NFs and some slice-specific NFs. In an extreme case, a network slice might be constructed completely from slice-specific NFs. A highly secure slice that requires complete isolation from other slices is an example.

Figure 4-2 shows an example of how network virtualization and slicing can serve the needs of mobile broadband users, critical communications, and the Internet of Things (IoT). In this example, each category of usage has its own slice where the virtualized network services are placed either at the network core or at the network edge in order to best serve specific needs.

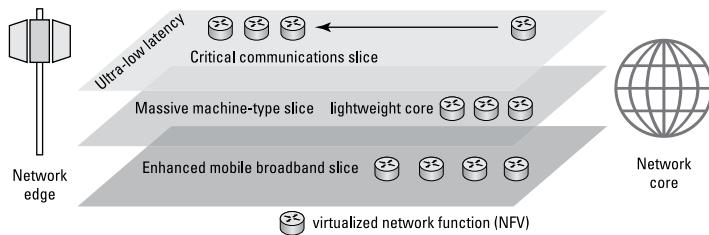


Figure 4-2: NFV and slicing enable the 5G network to better serve specific needs.

This allows a provider to create a single, highly flexible virtualized, software-defined network instead of building multiple purpose-built networks.

Chapter 5

Ten Great 5G Solutions

In This Chapter

- Ten ways 5G will enhance everyday life

This chapter takes a look at ten areas where 5G will bring changes to the way we live. Life is about to become a lot more interesting!

These areas fall into three categories, as shown in Figure 5-1: enhanced mobile broadband, critical communications, and massive Internet of Things.

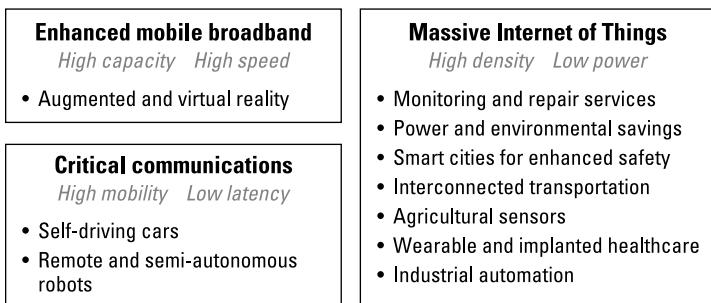


Figure 5-1: Ten ways 5G will change your life.

Augmented and Virtual Reality

Anyone who's seen an episode of *Star Trek* on TV has probably been exposed to the vision of virtual reality known as the *holodeck*. Of course, TV's version of VR was well ahead of its time, but that fictional innovation introduced the idea of a computer-generated experience that simulates or re-creates real-life situations and environments.

Eventually, AR and VR may look a lot more like the holodeck, but in today's world both technologies are only in their infancy. Users must don a headset that either displays a completely computer-generated world (in the case of VR) or overlays computer-generated content onto the user's view of the real world.

AR and VR have developed slowly because computer systems and wireless networks haven't offered enough performance to make the technologies very useful.

5G promises to rectify this situation by providing much higher data rates and greatly reduced latency.



5G will also enable next-generation AR and VR to provide *six degrees of freedom (6DoF)*, so users will be able to move more naturally and therefore have a more realistic experience.

Self-Driving Cars

Self-driving cars are one of the hottest topics in the automobile world today. Planners foresee a time when people will get into a vehicle, tell it where they want to go, and sit back and relax while that vehicle safely delivers them to the destination. Companies like Audi, Google, and Tesla have been working hard trying to make this future a reality.

Backers say that self-driving vehicles will be safer and more economical to operate, reduce congestion on the roads, and make looking for a parking place a thing of the past. While all of this may be true, much of that progress depends upon the ability of the autonomous vehicles to communicate with each other and with the transportation infrastructure. Today, such communication can be very difficult, unreliable, and have too much latency to accomplish those goals.

5G promises the capability for reliable vehicle-to-vehicle and vehicle-to-infrastructure communications while reducing latency so that autonomous vehicles can react more quickly to changing situations.

Government regulations will play a critical part in achieving widespread deployment of self-driving vehicles.



One of the promises of self-driving vehicles is that congestion on the roadways will be reduced because vehicle-to-vehicle communications will enable those vehicles to drive more closely to each other than would be safe for human drivers. As a side benefit, the shorter following distances promise to also provide less drag, thereby reducing fuel consumption.

Remote and Semi-Autonomous Robots

Robots have become a mainstay of modern manufacturing. They perform tasks that are too repetitive or too dangerous for humans and they don't need rest breaks.

Boston Dynamics, a sister company of Sprint's in the Softbank family, builds advanced robots with remarkable behavior: mobility, agility, dexterity, and speed. See <https://www.youtube.com/watch?v=fUyU3lKzoio>.



5G is especially important when robotics is combined with IoT-based sensors to allow immediate feedback between the sensors and the robots.



Robots will increasingly handle dangerous tasks such as earthquake rescues, resolving problems in nuclear reactors and underground mines, and providing battlefield support. 5G will be vital to enabling the robots to perform these tasks and communicate their status.

Monitoring and Repair Services

Very few problems magically solve themselves. Unfortunately, many problems have the capability of causing catastrophic failures if the problem isn't detected and resolved before it becomes even worse. Usually, those failures happen at inopportune times such as Christmas morning just before the whole family is expected to arrive for a big, festive dinner.

One of the great promises of the IoT is that many common devices such as home appliances will become smart enough

to recognize an impending failure. Theoretically, you'll get enough warning so that you can schedule a repair before that appliance completely stops working. In some cases, the device may even automatically schedule a visit by the service technician.

Smart devices will use the 5G network to communicate their status and help ensure that your future holidays don't become a disaster because a ten-cent part caused your entire kitchen to fall apart.

Power and Environmental Savings

A lot of energy is wasted because homes and offices aren't smart enough to reduce energy consumption based on when it's necessary to have the heat or lights on. Likewise, it's difficult for utilities to make the most effective use of alternative energy sources such as solar and wind power because of unpredictable supply and demand.

5G and IoT devices will combine to make systems more intelligent so that energy consumption can be reduced and alternative energy sources can be used more effectively. For example, utilities may have the ability to direct home energy storage systems like the Tesla Power Wall to store grid power when solar or wind power is abundant.



The low latency provided by 5G is vital to enabling the smart grid to control supply and demand for greatest energy efficiency.

Smart Cities for Enhanced Safety

The smart city of the future will have more efficient transportation systems that are also safer because they'll be able to detect and react to traffic more efficiently. Sitting at red lights when there's no cross traffic is not only frustrating but wastes fuel and increases your commute time. A smart city

grid will help to make traffic move more smoothly and reduce air pollution.

The smart city grid will also enhance public safety with intelligent video monitoring that may reduce crime. In addition, these systems will be invaluable to improving response to natural disasters. First responders will more easily determine where they are needed and how best to reach that location, especially if roadways or bridges are damaged.

5G will provide the necessary communications resources that enable the smart city grid to be more reliable and responsive.

Interconnected Transport Systems

Transportation costs can be a huge part of the cost of goods in the market. Anything that can make the transportation process more efficient increases profits, helps make vendors more competitive, and can reduce traffic congestion.

Shipping companies will be able to leverage 5G and IoT devices to enable real-time fleet tracking so that unnecessary delays can be avoided. They'll also be able to reduce fuel consumption by routing delivery vehicles around congestion.



If cities make their smart grid data available in real-time to transportation companies, overall traffic congestion may be reduced when delivery vehicles use alternate, less congested roadways rather than contributing to gridlock on over-crowded highways.

Agriculture Sensors

Modern farming operations are becoming more high-tech every day. IoT sensors and autonomous heavy farm equipment connected through the 5G network can make agricultural operations far more efficient and reduce the cost of producing our food.

IoT devices can be used to monitor livestock to ensure proper growth and good health. In large operations such monitoring is vital to make sure that animals are receiving proper nutrition and to prevent the spread of disease, which can happen very quickly when a lot of livestock are concentrated in an area.

Monitoring by IoT devices connected to the 5G network can also be crucial to ensuring food safety. The sooner a problem can be detected, the faster it can be resolved with the smallest possible impact on product.

Healthcare

Wearable or implanted medical devices such as pacemakers and insulin pumps can make a huge difference in the quality of people's lives. With 5G connectivity, those devices can help monitor a patient's health and can be real life savers. Future connected medical devices will add even more functions and help doctors provide better care for people.

As the population ages, more people suffer from ailments like dementia or Alzheimer's. The 5G network will likely play an increasing role in helping monitor early-stage patients to enable them to continue an independent lifestyle for as long as possible. Wearable 5G devices will also make it possible to quickly locate someone who may have become confused and wandered away from home.

Factories of the Future, or Industrial Automation

Automating the factory of the future is another exciting place where 5G will play an important role. Things like autonomous fork lifts and tracking materials will be enabled. For example, small, inexpensive, low-power sensors may improve product tracking and thus reduce waste and lost time.

It's likely clear that this chapter has only scratched the surface of the important and exciting changes that 5G will bring.



Works for Business™



Your network should work for your business.

Legacy networks just aren't optimized for the opportunities of today's enterprises. What impact could you make with the speed, capacity and low-latency of 5G? Sprint's network is ready to work for you.

Find out more: sprint.com/worksforbusiness

Converged • High capacity • High speed •
Multi-spectrum • Secure and resilient • Managed

© 2018 Sprint. All rights reserved. Sprint Business and Sprint logo are trademarks of Sprint.

These materials are © 2018 John Wiley & Sons, Inc. Any dissemination, distribution, or unauthorized use is strictly prohibited.

Begin planning for the 5G future

5G, the next iteration of wireless networks, will drive new levels of innovation and progress around the world. This book shows you what you need to know about the technological innovations that are being developed today to enable a 5G future.

- **Understand 5G's evolution — trace the progress of wireless technology right up to the dawn of 5G**
- **Look to the future — imagine greater speed, responsiveness, and scale**
- **Be ready — understand the 5G standards and timeline**
- **Explore the changes still to come — see the implications for enhanced mobile broadband, massive Internet of Things, and critical communications**



Open the book and find:

- How 5G will increase capacity, improve speed, and reduce latency
- How millions of small antennas will change the wireless landscape
- How the core network will evolve
- What 5G New Radio will mean
- Why 5G is ideal for Internet of Things devices

Go to **Dummies.com®**
for more!

Brian Underdahl is a well-known author and technologist who enjoys making complicated topics easy for ordinary people to understand.

FOR
DUMMIES®
A Wiley Brand



Also available
as an e-book

ISBN: 978-1-119-49269-6
Not for resale

WILEY END USER LICENSE AGREEMENT

Go to www.wiley.com/go/eula to access Wiley's ebook EULA.