SIERRA WIRELESS

5G for IoT?
You're Just in Time.

A SIERRA WIRELESS WHITE PAPER

With all the talk about 5G these days, it can be hard to decipher what is applicable for IoT applications, when it will be available and what the transition looks like for platforms currently on 2G, 3G or 4G technologies. The good news is that for companies in the IoT, true 5G is still on the horizon, making now the perfect time to start planning for its arrival.

The 5th generation of cellular technology, commonly referred to as 5G, is slowly becoming a reality. What started in 2012 in the standards bodies has now evolved into a set of wireless technologies that are making the transition from standardization to commercialization. This paper looks at what that means for deployments in the Internet of Things (IoT).

HOW ARE CELLULAR STANDARDS DEFINED?

The International Telecommunications Union (ITU), the United Nations agency tasked with coordinating telecommunications operations and services worldwide, provides guidance by outlining the requirements for cellular operation. The 3rd Generation Partnership Project, better known as the 3GPP, follows this ITU guidance to develop specifications. The ITU then evaluates the specifications and, having given their approval, issues declarations of compliance.

5G is Coming in Waves

The transition to 5G isn't happening all at once. As with 3G and 4G before it, 5G is arriving in phases, following a path to commercialization that reflects what's easiest to deploy. That means fixed wireless has come first, with consumer and industrial applications following thereafter.

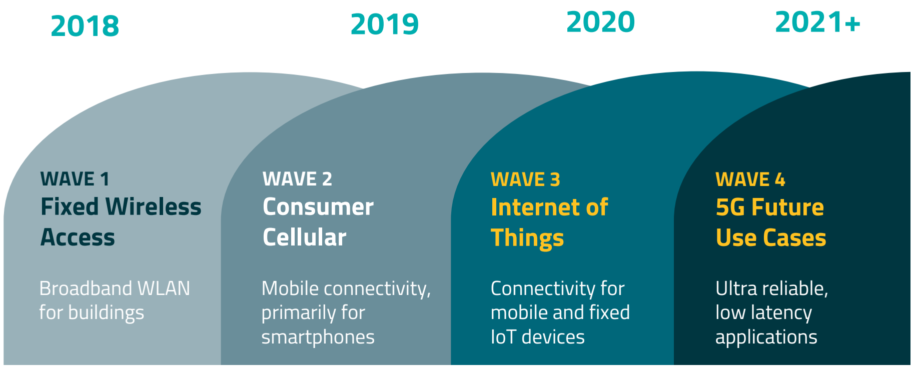

Figure 1: 5G Commercialization Timeline

- **WAVE 1: FIXED WIRELESS ACCESS**

  As its name implies, Fixed Wireless Access (FWA) delivers cellular connectivity to a fixed location, such as a private home or business. FWA is often the first cellular service to support a new generation of operating standards; it's relatively quick to roll out small local areas which can still be useful for FWA since there is no mobility requirements for the FWA use case. Widespread trials of 5G FWA began in 2018 and service is expected to expand rapidly in 2019.

- **WAVE 2: CONSUMER CELLULAR**

  Since smartphones have become such an important part of everyday life, they are an early focus of 5G consumerization. Network operators are moving ahead with deployments and smartphone manufacturers are introducing new models that are 5G ready. 2019 is widely viewed as the year that 5G smartphones, and the networks that support them, will really begin to take off.

- **WAVE 3: INTERNET OF THINGS**

  The IoT is an increasingly important market for cellular, but consumer demand is still a more immediate focus for commercialization. New 5G device capabilities, supporting mobile and fixed low and high bandwidth IoT deployments, are expected to start coming online in 2020. That makes 2019 an ideal time to start planning for and designing in 5G functionality.

- **WAVE 4: FUTURE 5G USE CASES**

  The first 3 waves of 5G are really evolutions of existing cellular use cases delivering important enhancements to both Low Power Wide-Area (LPWA) applications and high-speed, high-bandwidth mobile broadband applications. But the "what's new with 5G" in terms of high reliability and extreme low latency, private networks on unlicensed spectrum, and satellite communication isn't expected to come online until late 2021 or early 2022. This is when we will start seeing features to support applications like autonomous driving as well as factory automation (aka smart factories).

5G is Everything Cellular, Today and Tomorrow

Cellular is now part of a very wide range of applications, and 5G reflects that. In addition to supporting the familiar use case of a smartphone streaming the latest video, 5G also has to meet the requirements of IoT devices, which have their own range of requirements and use cases. An IoT device can be anything from a low-power sensor, transmitting only small amounts of data intermittently, to a sophisticated edge device that relays real-time video to and from the cloud. 5G covers all of that.

5G is also intended to last well into the future, so it anticipates the requirements for use cases that are around today, such as smart energy applications, as well as those that are still some time away, such as driverless cars communicating with other vehicles and highway infrastructure in real time.

To address all these various requirements, 5G covers three categories of communication, each aimed at a different set of use cases and operating conditions. Broadly speaking, these use cases cover (1) low-power IoT applications, referred to as Massive, Machine-Type Communication (mMTC), (2) industrial and critical IoT applications, referred to as Ultra-Reliable, Low Latency Communications (URLLC), and (3) the consumer market, referred to as Enhanced Mobile Broadband (eMBB).

Acronym	Full Name	Key Characteristics	Serviced By		
			5G LTE-M/ 5G NB-IoT	LTE Release 15	5G NR
mMTC	Massive, Machine-Type Communication	Low cost Low power High coverage High density	x		
URLLC	Ultra-Reliable, Low-Latency Communications	Very low latency Very high reliability Very fast handoffs High mobility		?	x
eMBB	Enhanced Mobile Broadband	High peak speed High average speed Spectral efficiency High capcity		x	x

1. **MASSIVE, MACHINE-TYPE COMMUNICATION (MMTC)**
   This is really the evolution of Low-Power Wide-Area (LPWA) LTE technologies for applications requiring low-cost, low-current operation, with high coverage in high-density operating environments. 5G addresses this use-case with evolved versions of the two LPWA standards most widely used in the IoT today, LTE-M (which operates inside the LTE band) and NB-IoT (which operates at 200 kHz). These technologies are designed for large-scale deployments of low-power devices, such as sensors, for use with smart cities, smart logistics, smart meters and other applications.
2. **ULTRA-RELIABLE, LOW-LATENCY COMMUNICATIONS (URLLC)**
   This is designed primarily for the Industrial IoT (IIoT) or Industry 4.0, with applications like factory automation, smart city 2.0, and, in the future, autonomous vehicles. Ultra-low latency and very high reliability are key concerns in this area. Quick handoffs and high mobility are also important, especially where vehicles and other mobile applications are concerned. 5G addresses this category mainly with the recently defined radio access technology, called New Radio or NR. The 5G NR technology supports very high bandwidth, in the millimeter Wave (mmWave) spectrum, and is one of the biggest differences between 4G and 5G.
3. **ENHANCED MOBILE BROADBAND (EMBB)**
   This is what next-generation smartphones will use, and it's where most consumers will experience 5G. It includes support for high-bandwidth applications, such as immersive video, augmented reality and 3G video. High peak speed and high average speed are important here, as is the need to use the spectrum efficiently while maintaining high capacity. 5G addresses this category in two ways:
   a. Standalone (SA): using the same technologies as URLLC, namely 5G NR.
   b. Non-standalone (NSA): using a combination of LTE and 5G NR technologies to achieve the high-bandwidth.

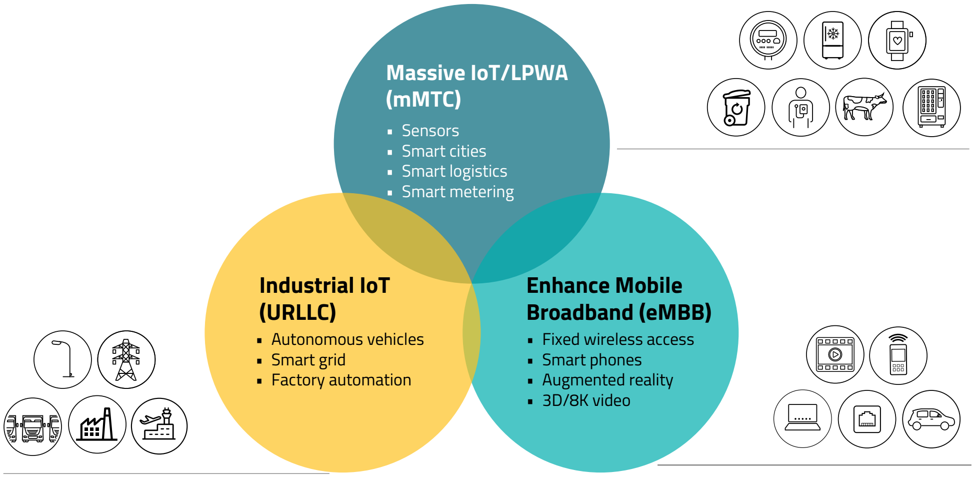

Figure 2: 5G Addresses Current and Future Use Cases in Consumer and IoT Markets

Some of 5G is Incremental

Some of the improvements associated with 5G are extensions and evolutions of what's currently in use today. Here's a quick look at what's included in the new 5G versions:

- **5G LTE-M AND 5G NB-IOT**
  5G for mMTC is based on enhancements to LTE-M and NB-IoT and promises to increase coverage, device density and battery life.

  Coverage

  5G is expected to offer coverage ratings above 164 dB Maximum Coupling Loss (MCL), so transmissions will go farther and are more likely to reach their target when passing through cement walls or traveling underground.

  Device Density

  5G promises increased capacity, with support for as many as a million devices or more per square kilometer. The ability to support more devices comes from several features, including flexibility in scheduling, improved frequency division multiplexing, higher-order modulation (64 QAM) and support for an earlier data-transmission scheme.

  Battery Life

  5G will also deliver improvements in current consumption, so low-power applications will need even less energy to run. Power-saving features, such as a new synchronization signal, a wake-up signal and a system-change notification flag, lighten the power load and help extend battery life to more than 15 years in the field. An early data-transmission scheme helps ease power requirements, too, as does relaxing requirements for cell monitoring.

  All of these 5G mMTC features will be available in future firmware versions, so today's already-deployed LTE-M and NB-IoT hardware is future-proof to 5G.

- **LTE RELEASE 15**
  LTE Release 15 will be marketed as 5G and retain backward compatibility. Even though the 4G LTE specification includes support for very high speed devices, which can exceed the 5G requirement of 20Gbps, this has not been commercialized. To meet the eMBB 5G speed requirement, both the LTE devices and LTE infrastructures would likely need hardware upgrades to add more carriers for aggregation and more antennas for improved MIMO support.

  LTE Release 15 also adds some features such as increased mobility (500 km/hour), better control plane latency (20 ms), improved user plane latency (1 ms), higher reliability (99.999%) and lower network power (80% sleep). LTE Release 15 also extends the reach, making it possible to service new applications, including interactions between devices (D2D), vehicle-to-everything (V2X) communication, high-precision positioning and improved operation in unlicensed spectrum (LAA).

What's Really New is 5G NR (mmWave)

Perhaps the biggest change with 5G is the addition of the New Radio (NR), which supports mmWave and opens up a whole new category of cellular applications. mmWave operates between 20 and 300 GHz, which is a massive span of untapped spectrum bandwidth. As a result, mmWave delivers data rates many times higher than today's average broadband connection, which operates within 0.6 and 5 GHz. In theory, 5G NR can reach peak rates of up to 77 Gbps in Frequency Range 1 (FR1), below 6 GHz, and up to 216 Gbps in Frequency Range 2 (FR2), between 24.25 and 52.6 GHz.

5G NR exceeds LTE Release 15 in other areas, too. The aggregated bandwidth for 5G NR can be as high as 6400 MHz, where LTE is limited to 600 MHz. Latency ratings are better, too, with 5G NR offering a control plane latency of 10 ms compared to LTE's 20 ms, and user plane latency of 0.1 ms to LTE's 0.85 ms. The network power savings are higher, too, with 5G NR supporting above 99% sleep.

5G NR includes several features that will enhance performance in higher portions of the spectrum, increase data rates, improve spectral efficiency, and reduce latency.

UNIQUE 5G NR TECHNOLOGIES

Higher Spectrum	• **Flexible numerology** – LTE supports a subcarrier spacing of only 15 kHz. 5G NR extends this to add 30, 60, 120 and 240 kHz spacing. • **Beamforming** – Up to now, mmWave has mostly been used for line-of-sight communication, which has a shorter range, especially in urban environments. To extend the range of mmWave, 5G NR uses beamforming, which focuses the signal into a narrow area and sweeps the beam across areas.
Higher Speeds	• **Selective HARQ** – Selective Hybrid Automatic Repeat Request is a better process for the retransmission of large data blocks, which occurs at higher speeds. Where LTE sends one big block, 5G NR can selectively send smaller segments to improve retransmission
Lower Latency	• **Faster TDD** – 5G NR supports much faster switching between uplink and downlink, which reduces latency. • **Pre-emptive scheduling** – Higher-priority data can overwrite or pre-empt lower-priority data, even if the lower-priority data has already started to transmit. • **Shorter minimum scheduling unit** – Trimming the minimum scheduling unit to just two symbols improves latency. • **Inactive state** – The time required to move in and out of the connected state (the state used for transmission) is shorter, making the UE more responsive.

Spectral Efficiency	• **100/400 MHz channel** – LTE uses a channel width of 20 MHz, while 5G NR uses a channel width of 100 MHz below 6 GHz and 400 MHz above 6 GHz. As a result, NR at 100 MHz can transmit a single set of signaling where LTE at 20 MHz would need to transmit five. • **Improved coding**– For error correction, LTE uses Turbo codes, but 5G NR uses Low-Density Parity Check (LDPC) and Polar, which simplifies computations and thereby makes it easier to handle large data blocks. • **Dynamic TDD** – Allows the time spent on the downlink/uplink to change dynamically based on demand. • **Reduced broadcast overhead** – 5G NR removes many of the constraints posed by LTE on broadcasted overhead transmission, especially with the number of always-on signals. The 5G NR network has more ways to turn itself off when idle, to increase efficiency and save power. • **Uplink CP-OFDM** – Unlike LTE, which only supports SC-FDMA (also called DFT-S OFMDA) as its digital modulation scheme, 5G NR adds support for CP-OFDM, which provides simpler interference cancelation and multi-user MIMO support.

5G NR is not backward compatible with other forms of cellular. As a result, devices that are designed to operate in 5G NR systems will need to use new dedicated 5G NR hardware.

Also, in the same way that LTE is, after a decade of use, still evolving, 5G NR will evolve over time, too, with incremental advancements being introduced in the years to come. The work currently being done in 3GPP on the latest release of the 5G cellular standard (Release 16) is the next evolution which addresses enhancements for 5G NR, such as interference handling, multi-radio DC, URLLC enhanced, CA enhancements and mobility enhancements. At the same time, there is work underway to support new features for 5G NR, including things like unlicensed spectrum support, positioning, non-terrestrial networks and enhanced V2X.

5G Uses a New Core Network, Too

Thus far, our discussion of 5G has focused on the radio access network, with its support for evolved versions of LTE-M, NB-IoT, LTE and the New Radio. But for those interested in a more technical deep dive, 5G also introduces a new core network, aptly named the 5G CN. The 5G CN is a significant departure from the Evolved Packet Core (EPC) used with 4G.

The 5G CN uses a more flexible architecture with built-in features that make it easier to port functionality and deploy new services. The 5G CN structure also supports much lower-latency configurations, by allowing more flexible local break-out options and network slicing which is very useful for URLLC applications.

SUB-RELEASES OF 5G

3GPP Release 15 is associated with three sub-releases. Anyone considering 5G operation in the near term is likely to encounter these interim versions, so they're listed here.

- **Non-Standalone (NSA) with EPC [December 2017]** – Released before the 5G CN was officially defined in Release 15, this version supports LTE as the primary component, with NR as a secondary connection to the EPC.
- **Standalone (SA) NR/LTE with 5G Core [June 2018]** – Supports either 5G LTE or 5G NR connected to the 5G CN (but not both at the same time).
- **NSA with New 5G Core [March 2019]** – Also known as the "Late Drop," this version supports configurations where 5G LTE and 5G NR are connected to the 5G CN at the same time.

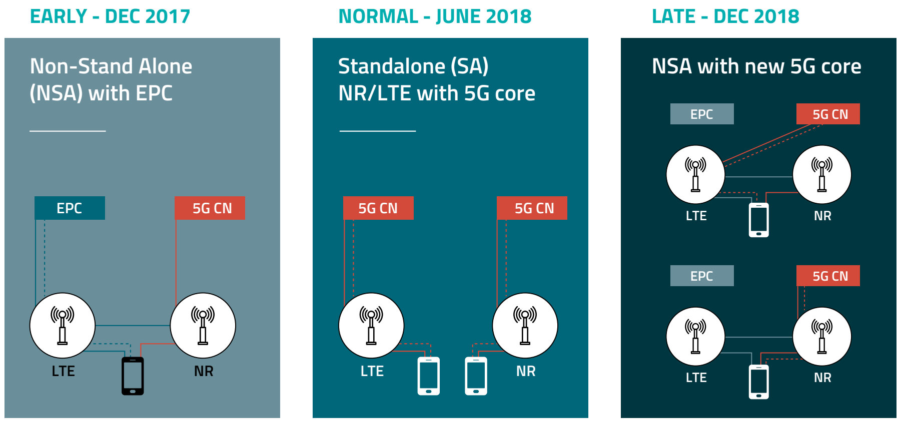

Figure 3: 5G CN Rel 15 Sub-Releases (2017-2019)

With 4G, user plane and control plane functions overlap to a certain degree. In the 5G CN, however, the core has been divided into two distinct areas of operation, the User Plane Function (UPF) and the Control Plane Function (CPF). Separating the two helps improve latency and makes the network setup more flexible. Multiple UPFs can be deployed locally, so packet processing and traffic aggregation can be performed closer to the network edge, resulting in faster responses and greater efficiency with lower network overhead.

Separating the UPF from the CPF also supports network slicing, which lets the 5G CN run multiple parallel core networks and thereby service each of the three categories of communications – mMTC, URLLC, and eMBB – simultaneously. For example, the slice of the 5G CN servicing mMTC can be optimized for capacity, to support areas that are densely populated with sensors and other low-power devices, while the slice servicing URLCC can be optimized for latency and availability.

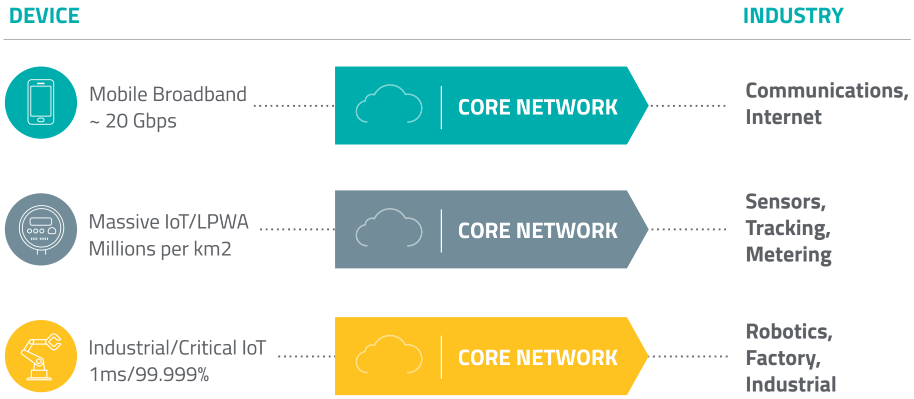

Figure 4: The 5G CN Supports Network Slicing

Another notable feature in the 5G CN is the Network Repository Function (NRF), which enables a service-based architecture. The NRF is used to register services, making it much easier to deploy new applications and make new features available to a wider audience. The 5G CN also uses familiar web interfaces, such as Java, to simplify development and reduce time-to-market for new applications. All these changes, make cloud virtualization more commercially viable. Virtualization, which makes it possible to run custom software functions on generalized hardware, makes it easier to deploy new services, too, since an instance of the 5G CN can quickly and easily be configured to run in the cloud.

The current version of the 5G CN (defined in Release 15), supports LTE Release 15 and 5G NR access only; 5G LTE-M and 5G NB-IoT (and possibly Wi-Fi) will be added in Release 16.

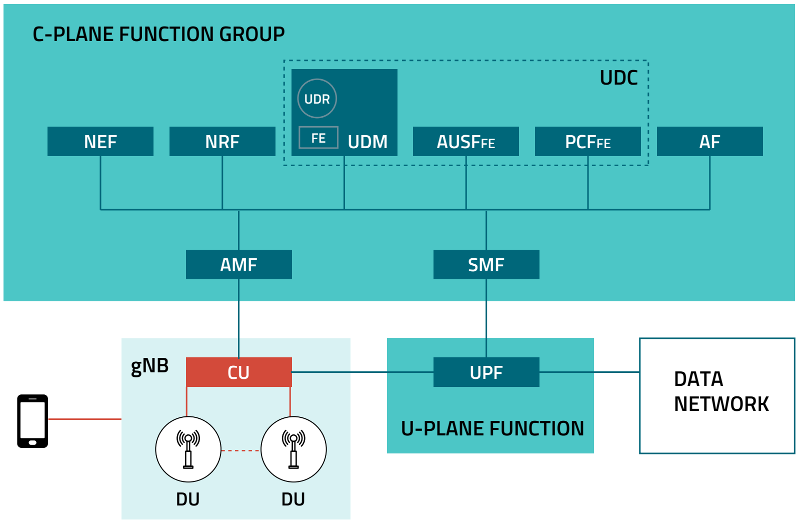

Figure 5: 5G CN is Agile and Cost-Effective to Operate

Start with Sierra

5G is here. But making the transition from final standardization to full commercialization will take time. That's especially true in the IoT, where 5G is likely to start making an appearance in 2020. That means now is the perfect time to be thinking about 5G, working with suppliers to evaluate options, making a plan and finalizing a design.

Sierra Wireless has played an active role in the development of 5G, by regularly attending 3GPP meetings, making recommendations for technology standards and following enhancements as they evolve. Our portfolio is designed to support 5G from day one, while delivering the flexibility needed to optimize operation down the road, as new features are released.

To learn more about 5G and what it might mean for your IoT deployment, visit www.sierrawireless.com/5G, where we have a series of webinars that look deeper into the promise of 5G.

Appendix

List of Acronyms and Abbreviations

3G	3rd Generation
3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
CN	Core Network
CPF	Control Plane Function
CP-OFDM	Cyclic Prefix Orthogonal Frequency Division Multiplexing
D2D	Device to Device
dB	Decibel
DFT-S OFDM	Discrete Fourier Transform Spread Orthogonal Frequency Division Multiplexing
eMBB	Enhanced Mobile Broadband
eMBMS	Evolved Multimedia Broadcast/Multicast Service
EPC	Evolved Packet Core
FR1	Frequency Range 1
FR2	Frequency Range 2
FWA	Fixed Wireless Access
Gbps	Gigabits Per Second
GHz	Gigahertz
HARQ	Hybrid Automatic Repeat Request
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information Technology
ITU	International Telecommunications Union
kHz	Kilohertz
km	Kilometer
LAA	License Assisted Access
LDPC	Low Density Parity Check
LPWA	Low Power Wireless Access
LTE	Long Term Evolution
LTE-M	Long Term Evolution – Category M1
MCL	Maximum Coupling Loss
MHz	Megahertz
MIMO	Multiple Input, Multiple Output

mMTC	Massive, Machine-Type Communication
mmWave	Millimeter Wave
ms	Millisecond
NB-IoT	Narrowband Internet of Things
NR	New Radio
NRF	Network Repository Function
NSA	Non-Standalone
QAM	Quadrature Amplitude Modulation
Rel 15	Release 15
Rel 16	Release 16
SA	Standalone
SC-FDMA	Single Carrier Frequency Division Multiple Access
TDD	Time Division Duplex
UE	User Equipment
UPF	User Plane Function
URLLC	Ultra-Reliable, Low-Latency Communications
V2X	Vehicle to Everything
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network