THE **ABC**'s OF

5G New Radio Standards

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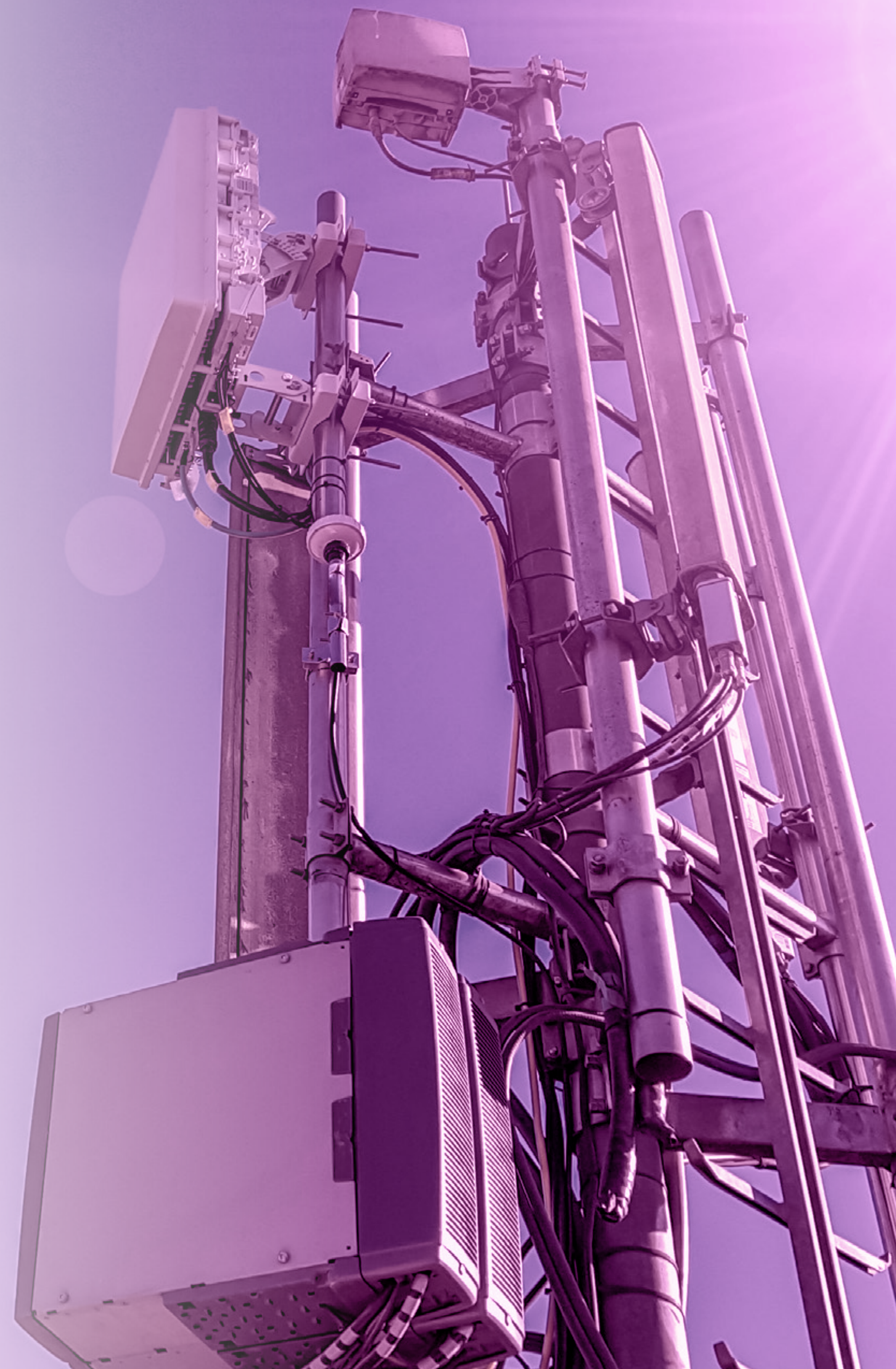
Introduction

A Primer on 5G Standards and Conformance

5G NR is very different from the previous generations of wireless standards. It introduces a new end-to-end network architecture that promises high data throughput and ultra-reliable low latency connections that open the door to new business models.

The 5G NR Release-15 standard was approved in June 2018, and it lays the foundation for a flexible, unified air interface that can support the many different use cases and services expected in 5G.

While Release-15 is nearly complete, many study and work items remain in development, and some aspects of the standard have yet to be specified, including how new devices and base stations will be approved. These areas have traditionally been addressed by conformance tests and by on-network validation tests.



This ebook outlines the 5G vision, the steps completed to date, and the next steps needed to fully realize the vision of 5G.

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The ABCs of 5G New Radio Standards

A A New Era of Wireless Communications

A New Era of Wireless Communication

The 5G vision defines an advanced mobile broadband communication system that can support an ultra-connected society.

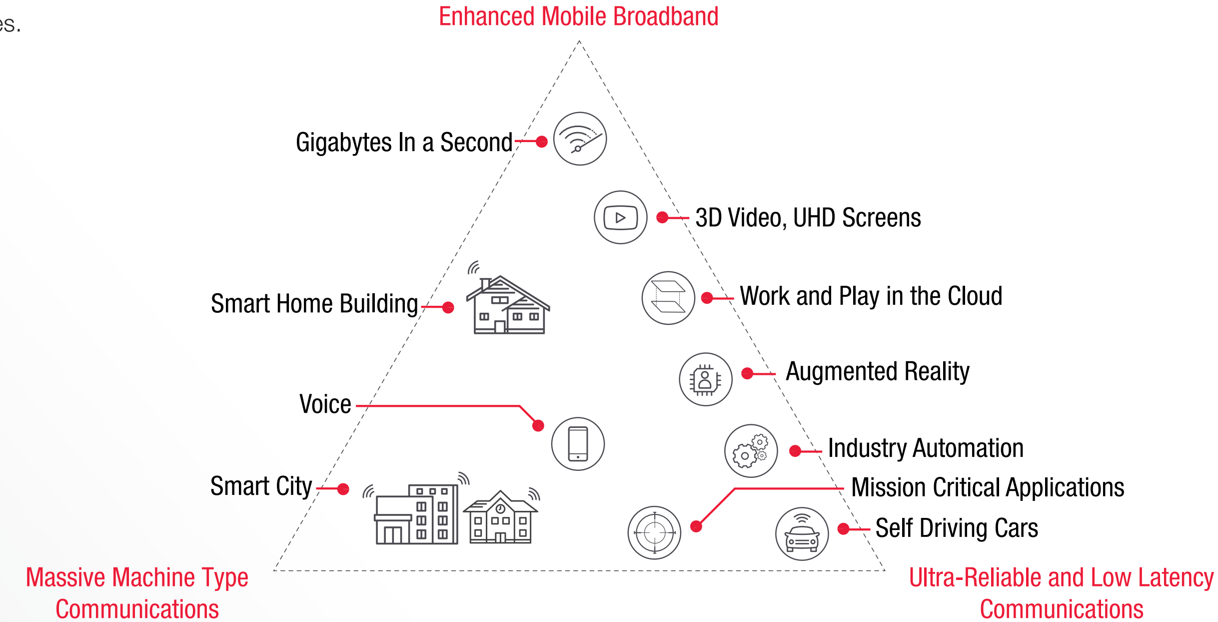
The **ITU** worked with operators, network equipment manufacturers, and standards organizations to define the **IMT**-2020 vision to deliver these three usage scenarios:

- Enhanced Mobile Broadband (eMBB)
- Ultra-Reliable and Low Latency Communications (URLLC)
- Massive Machine-Type Communications (mMTC)

5G NR Release-15, approved in June 2018, marks the start of a new era that will bring disruptive change across the industry. New applications and new business models will generate new revenue streams as market leaders move quickly to introduce new 5G products and services.

ITU: International Telecommunications Union
IMT: International Mobile Telecommunications

> "Two years ago, 5G was seen as a vision or even just a hype - with the closing of Rel-15 3GPP has made 5G a reality within a very short time. The outcome is an amazing set of standards that will not only provide higher data rates and bandwidth to end customers but which is open and flexible enough to satisfy the communication needs of different industries - 5G will be the integration platform for heterogeneous businesses."
>
> *Georg Mayer, Chairman of 3GPP TSG CT*



5G New Features and Technologies Enable New Use Cases

Vastly different performance requirements are needed to enable the different use cases and realize the vision of 5G.

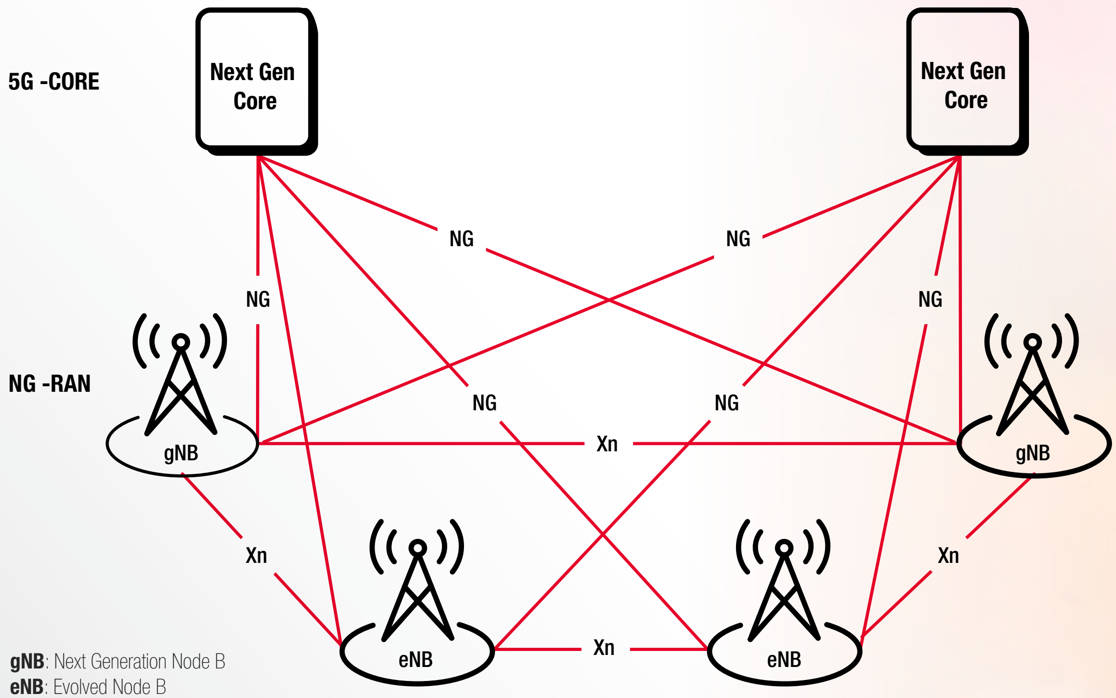
New features and technologies will be key to 5G implementation:

- Millimeter-wave (mmWave) operating bands up to 52.6 GHz with wider channel bandwidths up to 400 MHz enable higher data throughput for streaming of UHD videos and movies.
- Scalable numerology enables support for a variety of use cases where data rates could range from kilobits/sec (kbps) for IoT devices to gigabits/sec (Gbps) for enhanced mobile broadband.
- Mini-slots enable low latency response time for applications like autonomous driving and factory automation.
- Flexible assignment of resources through dynamic TDD (time division duplex), and bandwidth parts offer better use of spectrum to support the many different use cases.

Enhanced Mobile Broadband (eMBB)	Ultra-Reliable and Low Latency (URLLC)	Massive Machine-Type Communication (mMTC)
All data, all the time 2 billion people on social media	Ultra-high reliability Ultra-responsive	30 billion "things" connected Low cost, low energy
500 km/h mobility 10-20 Gbps peak data rates	<1 ms air interface latency 5 ms end-to-end latency 99.9999% reliable 50 kbps – 10 Mbps	105 to 106 devices per km2 1-100 kbps per device 10-year battery life

5G NR to Coexist with 4G Networks

For mobility, devices must maintain connection as they travel through the network. The expectation is that 5G NR is a totally new air interface that can operate alongside 4G LTE. The 5G Radio Access Network (RAN) will operate with both 5G NR (**gNB**) and LTE (**eNB**) base stations. The new RAN are interconnected through the Xn interfaces, and connected to the 5G core through the NG interfaces. 5G NR can operate in non-standalone mode (NSA), where the UE requires a legacy eNB with connection to the Evolved Packet Core (EPC) for control plane to support 5G NR communication. In standalone mode (SA), the 5G network can operate independently of the 4G core network. There are seven different connectivity options defined in the 5G NR specification, allowing network equipment manufacturers to plan upgrade paths to the next-generation core network.



gNB: Next Generation Node B
eNB: Evolved Node B

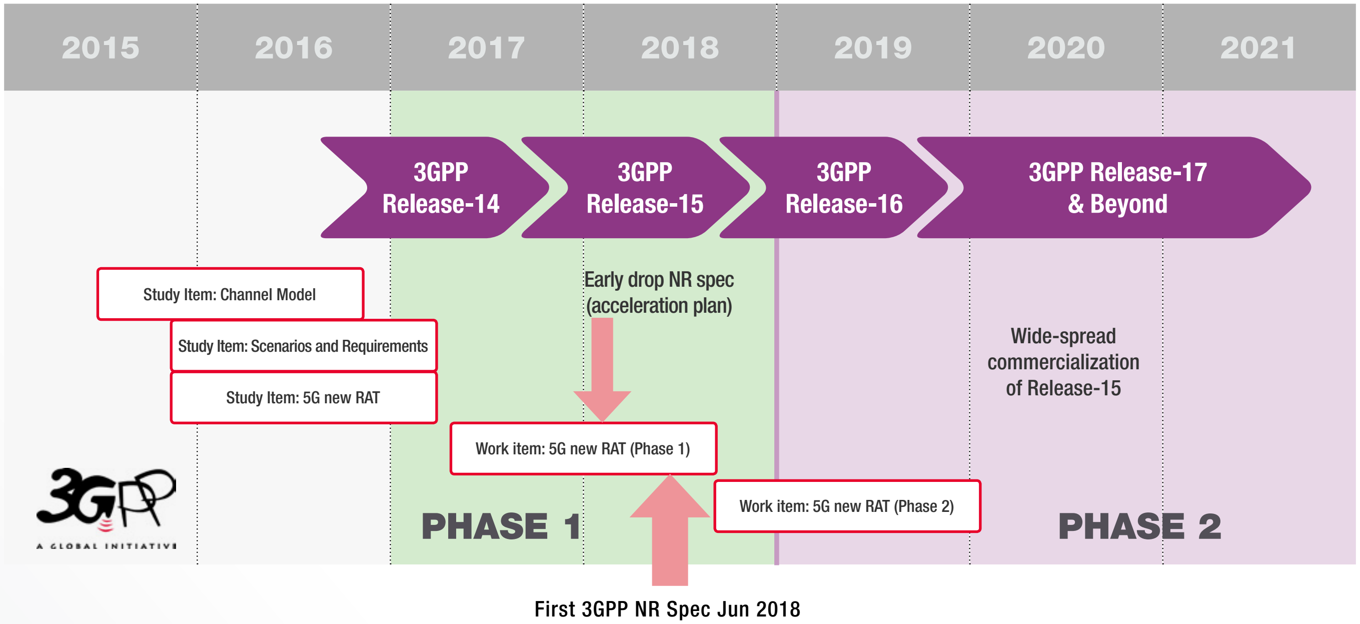
5G Timeline is Aggressive

Study items are followed by work items, followed by release of a specification. ITU and 3GPP use a phased approach to enable widespread commercialization by 2020. Field trials are already occurring in select cities around the world. The first commercial networks are expected to roll out in late 2018. Fixed wireless access in mmWave frequencies is one of the first use cases addressed by 5G.

Phase 1: Focuses on 4G LTE, 5G NR Release-15, and the next generation system architecture. NR Release-15 lays the foundation for eMBB and URLLC use cases.

Phase 2: Continues with 5G NR optimization and introduces new use cases with 5G NR Release-16 planned for the end of 2019. It is expected that NR Release-15 will be forward compatible with NR Release-16.

3GPP also continues to define enhancements to LTE-Advanced Pro (initially specified in Release-13 and Release-14) in Release-15 and Release-16.



Considerations

With the introduction of 5G New Radio standards, networks will need to support a diversity of 5G devices with many different usage scenarios.

5G NR Release-15 key features include:

- Operating bands extended into mmWave frequencies, up to 52.6 GHz initially and even higher frequencies in future releases
- Wider channel bandwidths up to 400 MHz in mmWave (i.e., frequency range 2), which can be further enhanced via channel aggregation
- Scalable numerology with flexible allocation of resources to support many different use cases and services (e.g., subcarrier spacing that scales, enabling variable slot duration for low-latency, time-sensitive applications)
- Dynamic time division duplex (TDD) and bandwidth parts, which deliver flexibility in resource assignments, and better spectrum utilization

LEARN MORE ABOUT 5G NR CHALLENGES

The 5G NR specifications lay the foundation for the flexible structure, but with the additional flexibility comes more complexity.

Your 5G NR designs will need to operate in new spectrum,with wider bandwidths, in standalone and non-standalone mode, and support new technologies including scalable numerology, flexible TDD, and bandwidth parts.

DOWNLOAD WHITE PAPER:

First Steps in 5G: Overcoming New Radio Device Challenges Series

B The Basics of 5G NR Standards

The Basics of the Specifications

5G NR Release-15 is a major milestone, enabling 5G radio access technology that is flexible enough to support sub-6 GHz and mmWave frequencies up to 52.6 GHz as well as new use cases and applications. Equally important, 5G system architecture must evolve to keep pace with the radio access changes.

3GPP is defining a new system architecture to support 5G requirements. The network needs to support the variety of 5G services, many different types of devices, and varied traffic loads. The 5G core network must be flexible and efficient. Many operators are moving to software-defined networking (SDN) and network function virtualization (NFV). Distributed cloud, network slicing, and self-optimizing networks (SON) are key enabling technologies. These technologies help virtualize the network architecture and management plane to create enhanced communication capabilities.

> “When we set out on this journey…there were really two things that drove 3GPP activities in this schedule, one was to make sure that we catered for those operators that want to deploy 5G early. The second is to make sure – content wise – that we are making the right set of features to serve as the first stepping stone towards the holistic 5G vision. With the content that was frozen in Release 15, last week, we achieved both of those goals.”
>
> *Balazs Bertenyi, Chairman of 3GPP RAN*

IMT-2020 Key Performance Indicators

3GPP specifications are split into multiple studies and work items:

- The RAN TR 38.912 study item covers new radio deployment scenarios, physical layer, layer 2, architecture for next generation RAN, radio transmission/reception, higher layers, network procedures, and more
- RAN TR 38.913 sets target Key Performance Indicator (KPI) requirements for the different deployment scenarios (i.e., eMBB, URLLC, and mMTC) as well as vehicle-to-everything (V2X) requirements

To meet the vision set forth by IMT-2020, the following 5G KPIs have been specified:

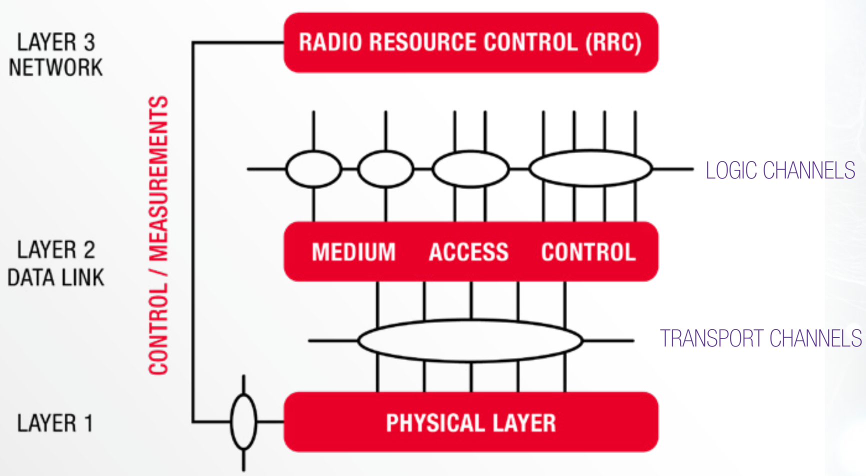
PEAK DATA RATE	20 Gbps in downlink 10 Gbps in uplink
PEAK SPECTRAL EFFICIENCY	30 bps/Hz for downlink and 15 bps/Hz for uplink
LATENCY	0.5 ms UL/DL (URLLC), 4 ms UL/DL (eMBB), 10 ms control plane
MOBILITY INTERRUPTION TIME	0 ms
RELIABILITY	URLLC $1\text{-}10^{-5}$ for 32 bytes with a user plane latency of 1ms. V2X $1\text{-}10^{-5}$, and user plane latency = 3-10 ms
CONNECTION DENSITY	1,000,000 device/km^2 in urban environments
UE BATTERY LIFE	mMTC should be beyond 10 years, 15 years is desirable
COVERAGE	164 dB
MOBILITY (UE SPEED)	500 km/h
NETWORK ENERGY EFFICIENCY	100x better than IMT-Advanced

Based on 3GPP TR 38.913 KPIs

The Layers of the Communications Stack

The radio interface between the UE and the network is described in Layers 1, 2 and 3 of the communications stack. These are commonly known as the physical layer, the data link layer, and the network layer. The physical layer represents the interface to the real world and includes the hardware and software to control this linkage. It provides a transport channel and specifies how information is transferred over the radio interface.

- The physical layer is covered in TS 38.200 series.
- Layers 2 and 3 are described in the 38.300 series. The data link layer enables data transfer between the different networks. Known as medium access control (MAC), it provides different logical channels to the radio link control (RLC) in the network layer.
- Layer 3 connects with the nodes in the network so that the UE can travel through the network.TR represents a technical report, or study, and TS represents a technical specification.



Radio interface protocol architecture around the physical layer (38.201)

3GPP RAN Study Items and Specifications

5G NR specifications are covered by the RAN working groups. The output of the workgroup is public; all documents, meeting reports, and published specifications are available on the 3GPP Website.

5G NR documents are represented in the 38.xxx series. Technical reports begin with TR and specifications begin with with TS. For 5G NR, RAN study items and specifications define functions, requirements, and interfaces to the networks. Shown here are 5G RAN 1-5.

> The 3GPP system architecture (SA) parallel work identifies the features and functionality needed to deploy a services-based operational network for 5G system. These specifications are represented in 3GPP TS 23.xxx documents.

	Study Items	Specifications
RAN1 Radio Layer 1	TR 38.802 Study on New Radio Access Technology: Physical Layer Aspects	TS 38.201 - 38.215
RAN2 Radio Layer 2 and Radio Layer 3	TR 38.804 Study on New Radio Access Technology: Radio Interface Protocol Aspects	TS 38.300 -TS 38.331
RAN3 Radio Network	TR 38.801 Study on New Radio Access Technology: Radio Access Architecture and Interface	TS 38.401 - 38.474
RAN4 Radio Performance and Protocol	TR 38.803 New Radio Access Technology: RF and co-existence aspects	TS 38.101 - 38.307
RAN5 Mobile Terminal Conformance Tests	No study item	TS 38.508 – 38.533

What's Next?

1. Stabilization of 5G NR Release-15 with cleanup of known issues through bug fixes or change requests. A late drop of Release-15 is planned for the end of 2018, and NR architecture options not completed will be addressed in an ASN drop in March 2019.
2. 5G NR non-standalone mode for fixed wireless access initial deployments expected near the end of 2018 and into 2019.
3. Release-16 work begins and includes identifying new types of services, devices, deployment models and spectrum bands with an emphasis on URLLC enhancements for industrial IoT, utilization of unlicensed bands, V2X, and UE positioning and power efficiency.

FOR MANY EQUIPMENT DEVELOPERS, THE REAL WORK STARTS NOW.

Designing new technologies that meet the new standards is important to deliver increased performance and dual connectivity with 4G, and to support new use cases will require a whole new level of test. With standards still evolving, you will need a test solution that can scale to cover sub-6 GHz FR1 frequencies and higher FR2 mmWave frequencies, wider bandwidths, denser waveforms, and a growing number of test cases.

LEARN MORE ABOUT 5G NR STANDARDS:

Webinar: Understanding 5G NR Physical Layer

Webinar: Completing Rel-15 of 5G NR Physical Layer

C Conformance and Acceptance Tests

Conformance and Acceptance Tests

Conformance tests ensure a minimum level of performance in UEs and base stations. UE requirements are very extensive to ensure RF transmission and reception, radio access, signaling and demodulation. Base station tests are structured around RF parameters.

Conformance tests only provide pass/fail results, offering no indication of how the device will perform when integrated into a wireless communications system. Vendors will test a wider set of parameters early using verification and regression testing to ensure quality and sufficient margins.

Pre-conformance testing is often done to ensure a "Pass" before spending time and expense on official conformance tests.

Device acceptance tests are commonly used to ensure a device meets the additional requirements specified by the operators.

"As we begin to transition to a new generation of wireless technologies, it's growing more important that we establish industry alignment. With 5G, this is more important than ever, as we're tapping into an area of the radio spectrum that has been a big unknown for the mobile industry. Being able to work closely with Keysight and leveraging their expertise with network simulation, RF and millimeter wave technologies is an advantage for our product validation efforts."

Woojune Kim, vice president of Next-Generation Strategy, Samsung Electronics.

Conformance Tests

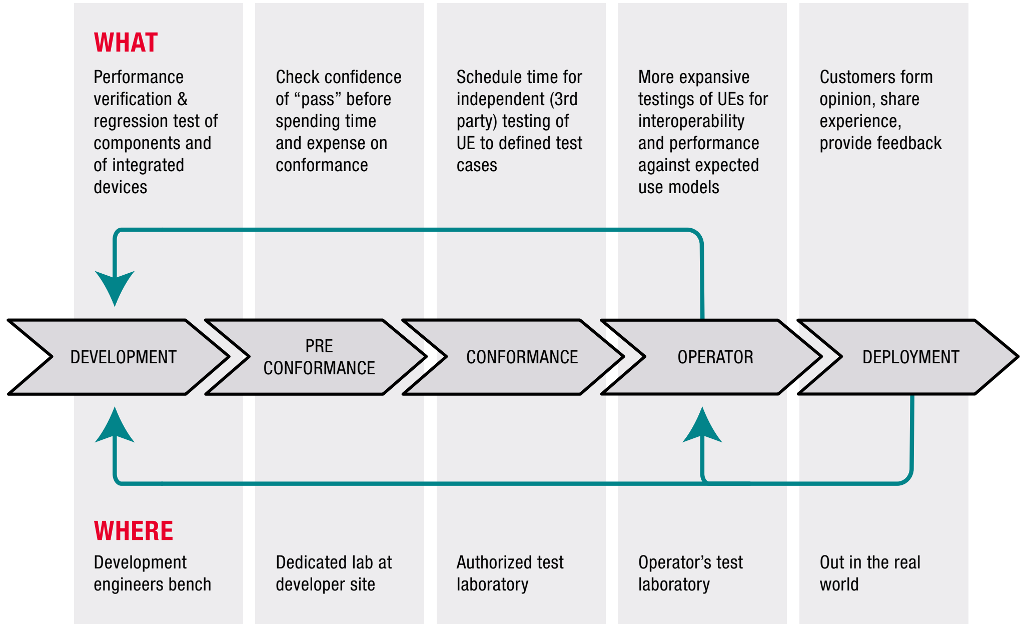
3GPP conformance tests define measurement definitions and procedures necessary to achieve compliance against the core specifications. UE conformance tests involve connecting a device to a wireless test system and performing the required 3GPP tests.

The 3GPP conformance specifications are divided into four main areas:

- RF transmission and reception performance – minimum level of signal quality
- Demodulation – data throughput performance
- RRM (radio resource management) – initial access, handover, and mobility
- Signaling – upper layer signaling procedures

The 5G RF transmission and reception performance test methods are the most mature, while test methods for device demodulation and RMM will require more complex testing solutions.

- UEs require radio transmission and reception, electromagnetic compatibility emissions (EMC), interworking operation with other radios, performance testing, protocol signaling tests, and RMM. The RF conformance tests focus mainly on RF transmitter characteristics, RF receiver characteristics, and RF performance characteristics.
- Base stations require radio transmission and reception and EMC emissions and immunity testing. The base station RF conformance tests focus on RF transmitter characteristics, RF receiver characteristics and RF radiated performance characteristics. Radiated OTA transmitter characteristics are required for specific base station classes, and specifically base stations operating in FR2.



A typical flow from development to deployment

Over-the-Air Tests

With devices and base stations operating in two frequency ranges (frequency range 1 (FR1) 450 MHz to 6 GHz and frequency range 2 (FR2) 24.25 to 52.6 GHz), many of the low frequency tests will be similar to 4G LTE tests. Base stations operating in FR2 will require radiated tests using over-the air (OTA) test methods. OTA test methods will also be used to validate device and base station beam steering functionality in multi-element antenna arrays that are integrated into RFICs at FR1 and FR2.

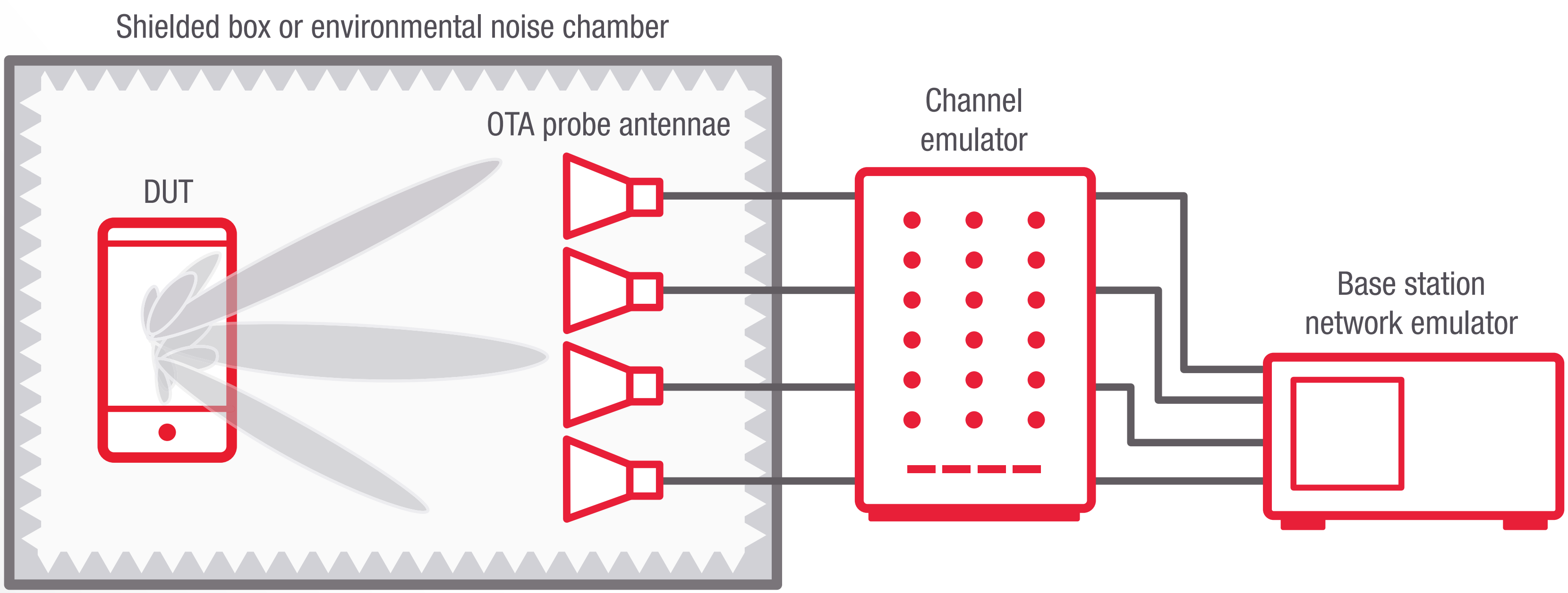
Specific measurements and methodologies for measuring mmWave devices over-the-air are still being developed in RAN5 with a target completion date of May 2019.

To date, 3GPP has approved three RF performance OTA test methods for UE devices:

DIRECT FAR-FIELD (DFF)	IN-DIRECT FAR-FIELD (IFF)	NEAR-FIELD TO FAR-FIELD TRANSFORMATION (NFTF)
A simple, comprehensive approach	Provides a near-field to far-field conversion enabling in a compact antenna test range (CATR)	A compact approach that can be lower cost
Can be very large with greater path for mmWave devices	Suitable for testing mmWave devices but not well suited for spatial RRM	Limited application for transceiver only, no receiver or RF parametric tests yet

Keysight OTA Solutions

Keysight's over-the-air test solutions include chambers, probing, and the test equipment used to address a wide range of RF, demodulation, and functional performance tests requirements from RF to mmWave.

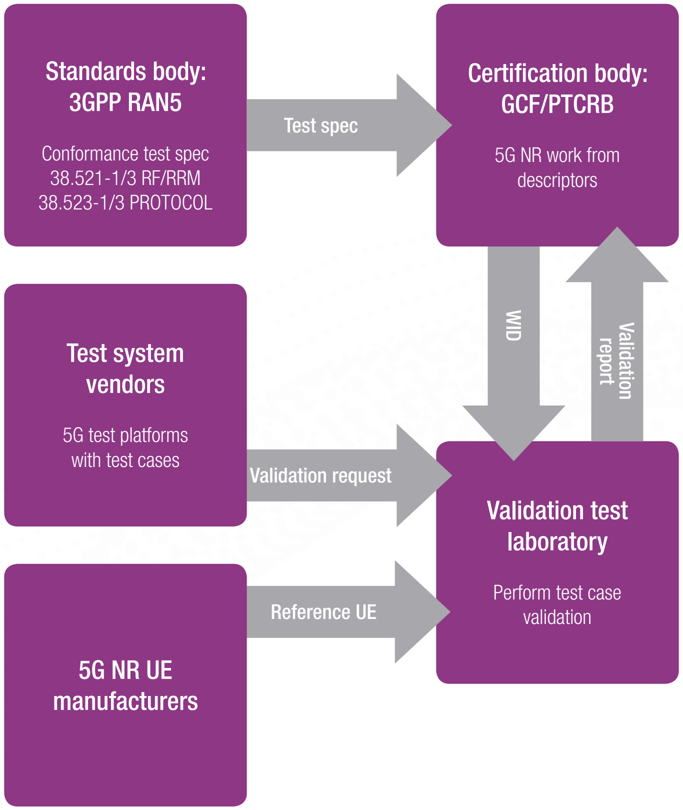


Certification

Conformance tests are conducted by 3rd parties. The test systems used to perform conformance tests must be validated and calibrated to ensure that the conformance test is performed with known uncertainties and under controlled conditions.

The following certification bodies oversee conformance tests:

- Global Certification Forum (GCF), under the umbrella of the GSM Association (GSMA), represents GSM and UMTS operators worldwide; it requires that the device be drive-tested.
- Personal communications system (PCS) is a variation of GSM for the 1900 MHz band. It is known as the PCS Type Certification Review Board (PTCRB). The PTCRB provides UE certification services for North American operators.



Standards bodies, certification bodies, test equipment vendors, and 5G NR device makers together ensure conformance to 5G specifications.

Device Acceptance Testing

Once the UE passes conformance tests and meets specifications, the next step is to validate the device on a specific network. Device acceptance testing is used to evaluate whether the device has adequate performance and helps identify and resolve issues before a device is allowed on the network in the hands of consumers. For example, some networks are marketed with attributes such as the fastest network, or most reliable network. In these cases, operator acceptance tests include performance and functional tests to ensure the device will deliver as promised.

The acceptance tests are owned by, and specific to, the network operators. Operators will stress the UE and the network, testing many different use case scenarios. One common test is battery performance under different usage scenarios of data consumption, talk time, or with use of location-based services. Evaluating real-world battery performance with many different permutations and combinations of activities requires many tests. Another common test is performance and user experience on a network. With the use of multiple different radio access technologies (RATs) in 5G, it is especially important to evaluate real-world handovers between radio networks.

Implications for Developers

IMPLICATION	CONSIDER
To date, conformance standards are less than half complete and will be phased in over time. Bringing devices to market without thoroughly testing RF performance, demodulation, RRM and protocol signaling can result in a non-compliant product.	Consider an **end-to-end test solution** that can create the appropriate test conditions, and measure conformance to the appropriate test parameters, incorporating fading and interference. Hardware and software should be refreshed to keep up with evolving standards that include higher frequencies, wider bandwidths, and denser modulation, to ensure devices are evaluated at their true limits.
Device acceptance tests are expected in 2019. Waiting to find issues during acceptance test could mean major rework late in development, resulting in higher costs and delayed time-to-market.	Consider using proven network emulation tools that can test KPIs in your development cycle to help identify potential issues early and reduce risk.
OTA tests are required for 5G. Direct far-field, indirect far-field, and near-field to far-field transformation test methods are approved by 3GPP, but test procedures and techniques are still being refined. It can take a significant amount of time and rework to investigate and implement an OTA test solution.	Consider an **OTA** test partner who has experience implementing the different methods.

Are You Ready for the 5G NR Standard?

5G NR introduces a new end-to-end network architecture that promises everything will be connected, all the time. With 5G NR Release-15 approved, developers can begin working on 5G devices and base stations. 5G NR introduced new technologies, increased performance requirements, established the need for dual connectivity with 4G, and defined many new test cases. 5G conformance requires a whole new level of test.

With standards still evolving through Release-16 and beyond, you will need test solutions that can scale to cover sub-6 GHz and mmWave frequencies, wider bandwidths, denser waveforms, and a growing number of test cases. Conformance and operator acceptance tests are still under development, meaning you will need a solution that is flexible and upgradable as test requirements evolve. Keysight's portfolio of 5G NR solutions address these challenges with tools to emulate, measure, and validate 5G RF and protocol signals from development through conformance and into acceptance tests, so you can develop more efficiently and accelerate your 5G NR designs.

LEARN MORE ABOUT 5G NR SOLUTIONS:

5G Chipset and Devices Solutions Brochure

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