5G Deployoment options
Spectrum is a key Component

Standalone (SA) vs. Non-Standalone (NSA)
Migration plan for Radio Access to Core Networks

NSA – 3GPP Release 15 NSA operation is based on Network Option 3 family which is "LTE assisted EPC Connected". The UE connects to both 5G NR and E-UTRA. For Control Plane (CP), it fully relies on the existing EPS LTE S1-MME interface procedures and LTE RRC protocol. For User Plane (UP) there are variations going into three sub-options like 3/3a/3x where the data can be split over LTE eNB or NR gNB.

SA - 3GPP Release 15 will contain SA Option 2. The idea behind Option 2 is Greenfield 5G based on 5G NR in Standalone operation and 5G Core.

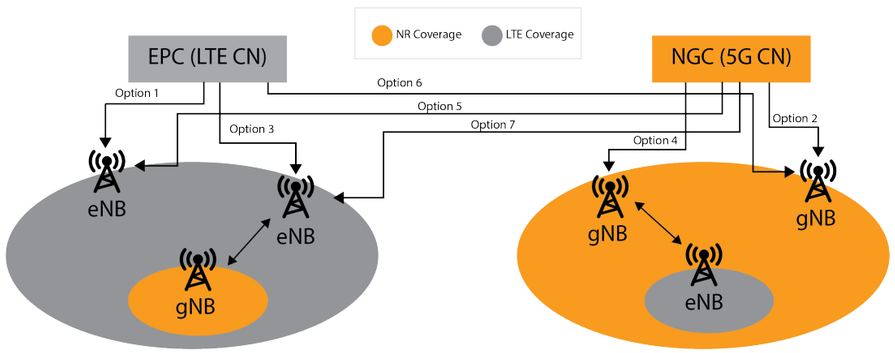
On one side, the scale of SA is a direct evolution to the next generation mobile network with lower complexity due to less interfaces being involved. On the other side, SA is bound to more massive early investments as well as by the introduction of new products at both network subsystems (Access + Core) at the same time.

1. 5G NR is defined with band agnostic operations, therefore, can be deployed on low, mid or high bands with no restrictions.

2. For Release 15, Bands are specified in two Frequency Ranges (FR):
   - **FR1.** from 450 MHz to 6000 MHz, Bands numbered from 1 to 255, Commonly referred to as Sub-6Ghz
   - **FR2.** from 24250 MHz to 52600 MHz, Bands numbered from 257 to 511, Commonly referred to as mmWave (although technically speaking mmWave starts from 30 GHz)

	Case 1: LTE Coverage + NR hot spot Non-standalone	Case 2: LTE Coverage + NR sub-6 carriers Non-standalone	Case 3: LTE + NR Standalone (Inter-RAT, no aggregation)
	NR mmW as hot spot + LTE Coverage NW	NR sub 6 carriers + LTE Coverage NW	NR Coverage NW / LTE Coverage NW
Advantage	Very wide BW, can achieve >5Gbps peak T-put	Better coverage Mature ecosystem	Better coverage Mature ecosystem Simpler migration path to 5GC
Challenges	Need mmW Very limited coverage Unreliable signal quality	Limited available spectrum Peak T-put ~4Gbps Fragement spectrum leads to multiple CA combos	Need wide enough contiguous spectrum for sub-6 NR Best case in HW cost & complexity

"Many carriers worldwide announced their support to NSA for the initial 5G NR rollout. While the exact use cases and benefits of the 5G Core are being studied and gradually understood, the driver for 5G NR in NSA options enables many operators to push for a rapid commercialization of the technology at the radio access part."



5G NR Key Components
Physical Layer Overhaul

Waveform and Multiple Access

Many options for waveforms were proposed at 3GPP, which required to set some performance targets to evaluate and compare each of them. The main targets proposed were the compatibility with MIMO, Spectral efficiency, Low Peak to Average Power ratio (PAPR), high time localization to support TDD systems and URLLC use cases, Acceptable complexity and low out of band emissions.

It was later agreed for 3GPP Release 15, that OFDM-based waveform with Cyclic Prefix (CP) will be supported for both DL and UL for 5G NR. DFT-S-OFDM based waveform will be also supported, complementary to CP-OFDM waveform at least for eMBB uplink for up to 40GHz. CP-OFDM waveform can be used for a single-stream and multi-stream (i.e. MIMO) transmissions, while DFT-S-OFDM based waveform is limited to a single stream transmissions targeting link budget limited scenarios.

Physical Channel Bandwidth. It was agreed that max channel bandwidth is 100MHz for sub6 and 400MHz for mmWave. Compared to LTE, 5GNR is designed to have higher Bandwidth efficiency, reaching 99% (compared to 90% in LTE, where 100 RB covered only 18 MHz in a 20 MHz Bandwidth carrier).

Numerologies. With the vast use cases planned for NR, a scalable and flexible physical layer design is required for each one and different and scalable Numerologies are to be supported. The main idea of OFDM is to divide a wide channel into orthogonal narrow subcarriers. A set of parameters define how this division is done and hence the OFDM system design, which are Sub-Carrier Spacing, Symbol length, cyclic prefix and transmission time interval (TTI). A Numerology is defined as a fixed configuration for this set of parameters. The different numerologies are applied to different deployments and will allow for different performance. For example the lower the Sub carrier spacing the larger the cell size will be, which will be suitable for the lower frequency deployment. At the same time larger sub carrier spacing will allow for better latency performance since the symbol duration will be shorter.

"The Carrier Bandwidth Part concept was proposed by MediaTek, to allow for the multiplexing of narrowband and wideband UEs and to allow for UE bandwidth adaptation for power savings."

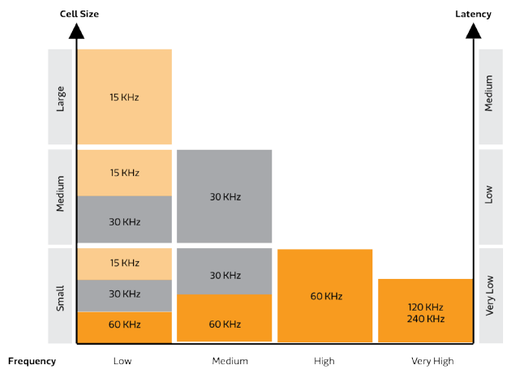
Frame Structure. Different Numerologies will be then translated in the number of slots per sub-frame. The higher the Sub-carrier spacing, the higher the number of slots per sub-Frame. Some new concepts were added to the frame structure definitions to deal with the different numerologies and the wide carrier bandwidth in 5G NR, notably the Carrier Bandwidth Part concept.

Modulation. For OFDM with CP and for both DL/UL: QPSK, 16QAM, 64QAM, and 256QAM. For the DFT-s-OFDM with CP for UL: π/2-BPSK, QPSK, 16QAM, 64QAM and 256QAM. 3GPP discussions are ongoing for adding the support of 1024QAM to the list of supported modulations.

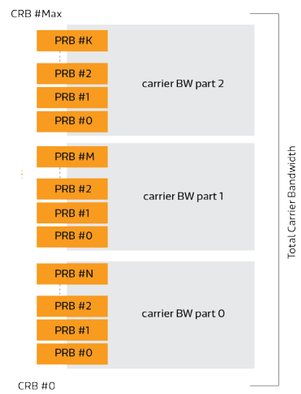
Channel Coding. Low Density Parity Check (LDPC) coding is replacing the Turbo coding that was previously used for LTE Data channels, and Polar Codes are replacing the Tail Biting Convolutional Codes (TBCC) used previously for LTE Control channels, except for very small block lengths where repetition/block coding may be preferred.

"MediaTek was also among the first to do interoperability testing on Polar Code with Huawei, for network capacity boost & low design complexity."

Numerologies vs. Frequency vs. Cell size



Carrier Bandwidth Part (CBP) concept



The Way Forward

Evolution towards Super Connected World

Release 15 is the first step on the 5G technology road, and more study items and work items are yet to come, and while the initial focus was to provide eMBB and partial URLLC support, more use cases and verticals are expected to arise and to be addressed in the next releases.

Aside than the few examples listed here, many more study items and features are expected to be addressed in next 3GPP releases for 5G, like EVS codec extension for immersive AR/VR experiences, Enhancements on public warning systems, enhancements for IMS to 5G core integration and 5G voice service continuity, Cellular IoT support in 5G, LAN support in 5G, Access traffic steering, 256 bit cryptographic keys and algorithms for security and the list keep getting bigger with new proposals as time goes by.

There are also increasing interest and participation in 3GPP from the satellite communication industry, who foresee the market potential for an integrated satellite and terrestrial network infrastructure in the context of 5G. Further studies and work are expected in the coming releases of 3GPP for using the satellite access in 5G.

Beyond 3GPP Release-15

In the course of adapting this template to suit your needs, you will see a number of different newsletter elements. The following is a list of many of the elements, accompanied by a brief definition.

New Multiple Access. Non Orthogonal schemes allow different users to use the same radio resources, and relay on advanced Multi User Detection (MUD) algorithms to recover users superimposed signals.

Self-backhaul. Self-backhauling is simply defined as the deployment scenario in which the access part – which is between the gNodeN and the UE - and the backhaul part – Between gNodeBs or gNodeB and Core Network – share the same wireless channel. Different sharing option could be applied by multiplexing the access and backhaul links in time, frequency or Space as in beam-based operations.

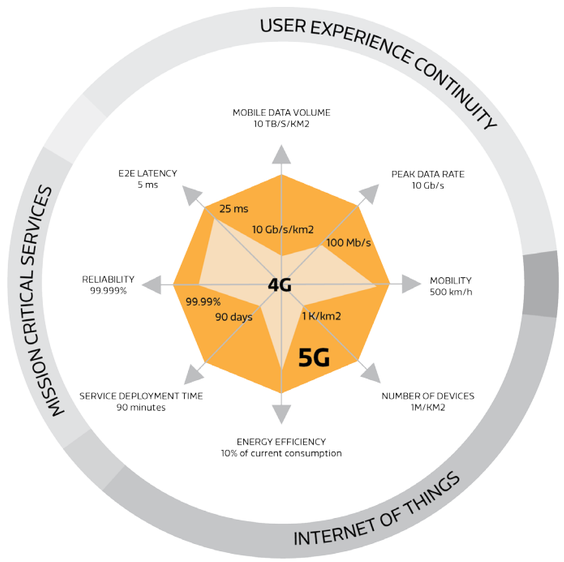
5G NR in Unlicensed Spectrum. Similar to LAA and Multefire for 4G, studies to adopt 5G NR in unlicensed spectrum will be further discussed in Release 16, taking into consideration both licensed assisted access and stand-alone deployments.
V2X for Automotive. In the next releases for 5G NR, more studies will focus on investigating and evaluating the possible reuse/enhancement of existing functionalities and architectures in 5G NR Phase 1 in order to support advanced V2X services, including but not limited to: platooning, extended sensor sharing, ranging to enhance positioning accuracy and other network based positioning enhancements, advanced driving, and remote driving.

"In recent trials, DoCoMo and MediaTek, demonstrated the possibility to have 2.4 times increase in mobile spectral efficiency, using NOMA (non-Orthogonal Multiple Access) proposed by DoCoMo and MUIC (Multi-user interference Cancellation) Developed by MediaTek."

5G is Getting Started ...

3GPP has accelerated the delivery of 5G, producing an interim set of approved specifications at RAN#78 Plenary in Lisbon, Portugal in the end of December 2017. This first set defines 5G New Radio (NR) in Non-Standalone operation (NSA) enabling 5G NR deployments using existing 4G systems (LTE EUTRAN and EPC). The specifications of 5G NR in Standalone operation are due for completion in June 2018, complemented by the complete set of specifications of the new 5G Core Network – hence the full 5G System - eMBB (enhanced Mobile Broadband), URLLC (Ultra Reliable Low Latency Communications) and mMTC (massive Machine Type Communications) as key 5G use cases.

The initial phase of 5G deployments lays at the eMBB-URLLC side of the triangle closer to eMBB. MTC has been already developed as part of 3GPP Release 13/14 LPWA technologies - NB-IoT and eMTC. These are expected to meet most 5G mMTC requirements, while full URLLC will require 5G Core deployment for full E2E latency reduction. Mission critical applications that are especially demanding for latency require full scale coverage as well which is hard to imagine for early deployments. So at the first stage, we expect to witness further bandwidth growth complemented by latency improvements on 5G NR, but also LTE. This will help to develop today's mobile broadband use cases to leverage emerging AR/VR (augmented reality/ virtual reality) applications, 360 UHD video and many more...



"MediaTek has been heavily investing in the development of 5G and is committed to accelerating its adoption, by bringing the technology to the mid-tier market from Day 1, in contrast to the usual premium-first approach."