Aalto University

# Lecture 6: Evolved RAN (5G NR)

ELEC-E7230 Mobile Communications Systems

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# Outline

- 5G NR (Release 15)
  - Requirements and drivers
  - Spectrum enhancements
  - Numerology/frame structure
  - Key RAN enhancements (massive MIMO focus)
  - Architecture
  - Future developments

# 5G NR Requirements

| Release | Rel.13 | Rel.14 | Rel.15 | Rel.16 | Rel.17 |
|---|---|---|---|---|---|
| Freeze date | 3/2016 | 3/2017 | 9/2018 (early drop)<br>4/2019 (late drop) | 7/2020 | TBC (Covid uncertainties) |
| Comment | LTE-A Pro | | 5G NR | | |

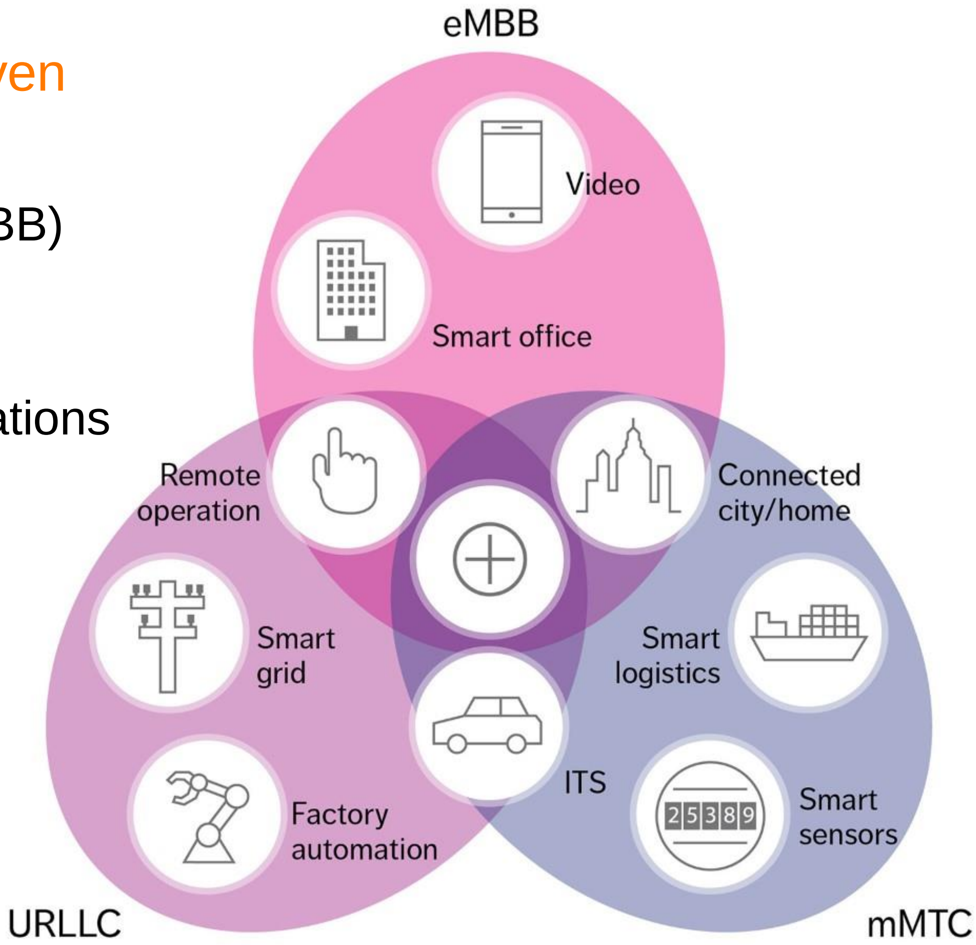
- Rel.13 and 14 = LTE-A Pro ("pre-5G")
- Rel.15: Specs for 5G New Radio (NR) start to appear
  - 5G NR Non-Standalone (NSA) operation→ "early drop" due to demand from operators
  - 5G NR Standalone (SA) operation
- Rel. 15 also includes work items continuing LTE enhancements (e.g. 1024 QAM)! (*not covered in this course*)
- Rel.16 continues enhancements to 5G NR → recently frozen but only brief overview in this lecture
- Work on Rel. 17 started earlier this year, but progress impacted by Covid-19 disruptions

# 5G Requirements

- Recall that in 1990s ITU IMT-2000 set requirements for 3G mobile broadband
- ITU IMT-Advanced in 2008 provided requirements which where targeted by LTE-Advanced
- ITU IMT-2020 specified in 2017 provides requirements targeted by 5G
  - Submission of 5G standard by 3GPP to ITU done in 2020
  - https://techblog.comsoc.org/2020/07/14/executive-summary-imt-2020-specs-defined-submission-status-and-3gpps-rit-submissions-2/

# 5G Requirements

- 5G requirements are use case driven
- 5G main use cases
  - Enhanced mobile broadband (eMBB)
  - Ultra-reliable low latency communications (URLLC)
  - Massive machine type communications (mMTC)
- Release 15 focused heavily on eMBB enhancements
  - Also focus of this lecture




Source: Ericsson

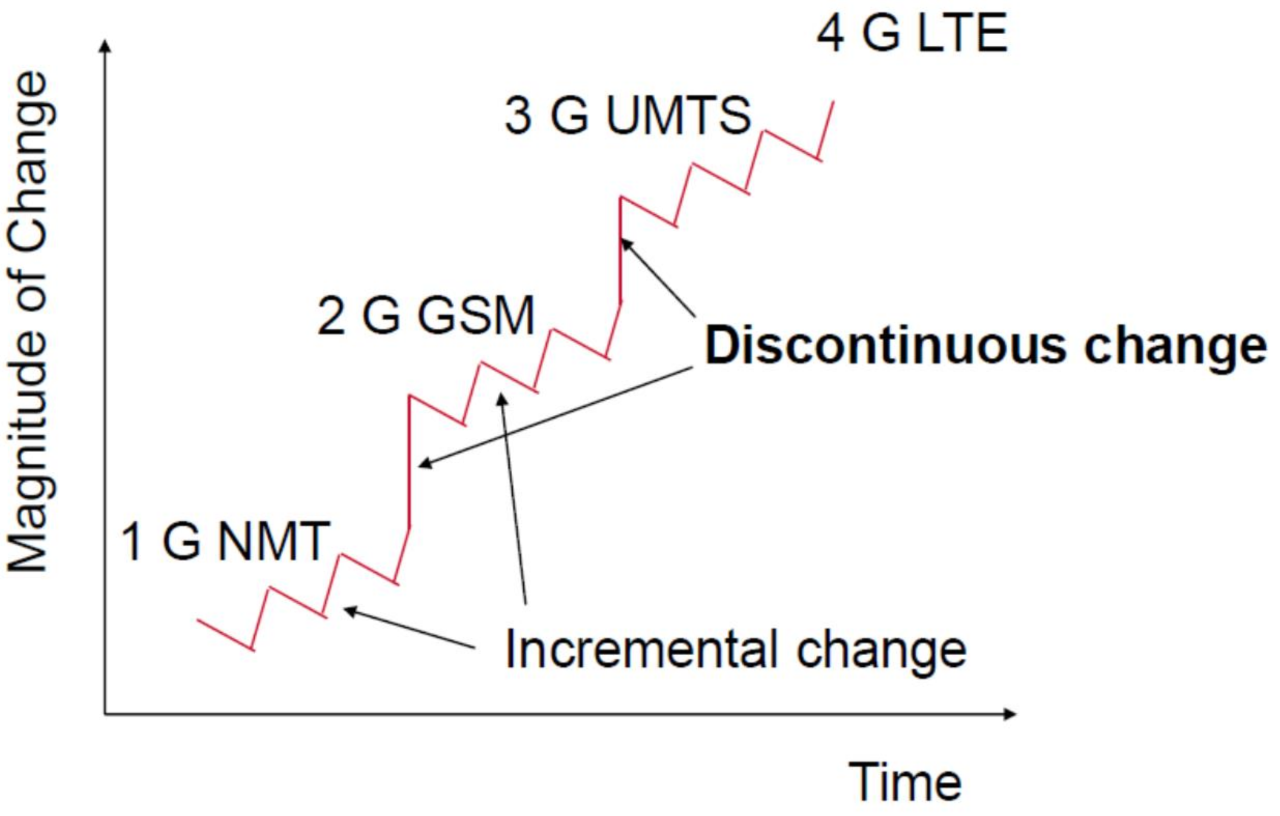
# 5G Requirements

- Use case driven targets
  - Peak rate: 20 Gbps (1 Gbps in LTE-A)
  - Cell edge user experienced throughput (5th percentile): DL 100 Mbps, UL 50 Mbps
  - Latency: Maximum 1 ms RTT delay for URLLC (10 ms in LTE Rel.8)
  - Connection density: 1 million connected devices per $km^2$
  - Service availability: 99.999%

| | | LTE Rel.8 | LTE-A target | 5G (IMT-2020) |
|---|---|---|---|---|
| Peak data rate | DL | 150/300 Mbps | 1 Gbps | 20 Gbps |
| | UL | 75 Mbps | 500 Mbps | 10 Gbps |
| Peak spectral efficiency | DL | 15 bps/Hz | 30 bps/Hz | 30 bps/Hz |
| | UL | 3.75 bps/Hz | 15 bps/Hz | 15 bps/Hz |

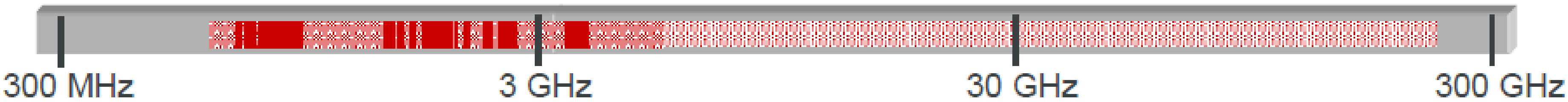
# Why 5G NR?

- Evolution of LTE is constrained by need for maintaining tight backward compatibility
  - → only incremental improvements (LTE-A, LTE-A Pro)
- Specification of new generation (4G→5G) provides opportunity for fresh start

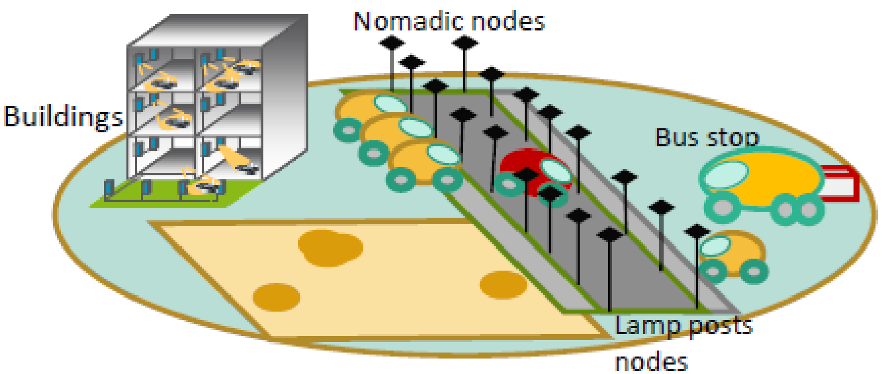



Source: adapted from Tushman, 1997

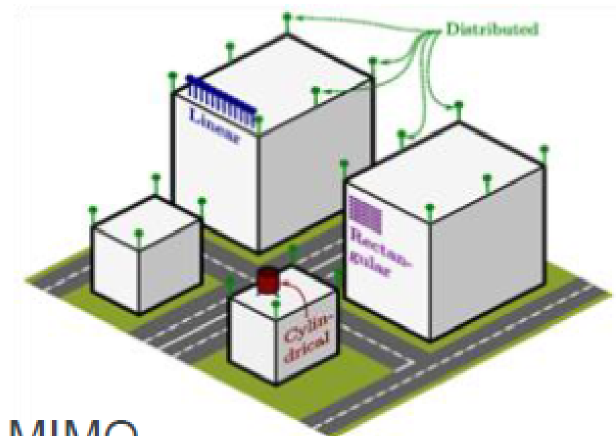
# Technology Enhancements for 5G NR




New spectrum bands and access methods

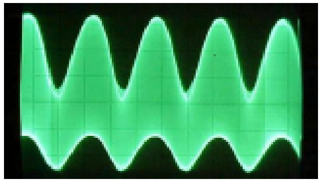



Dense and moving networks
Multi-hop wireless backhaul




MIMO
Massive multi-antenna systems

Context-aware interference and mobility management



Air interfaces for new applications and reduced signaling

Mobile
Device-to-device

Aalto University

Source: Anritsu

# 5G NR Spectrum Aspects

# 5G NR Frequency Bands

- 5G NR frequency bands roughly categorized in Frequency Ranges (FR) in 3GPP Rel. 15

| 3GPP frequency range designation | Corresponding frequency range |
|---|---|
| FR1 | 450-6000 MHz |
| FR2 | 24250-52600 MHz |

  - Low bands of FR1 (below 1 GHz)
    - Provides wide coverage in rural areas or deep in-building coverage urban/suburban scenarios
  - Rest of FR1 (1-6 GHz)
    - Offers good mixture of coverage and capacity benefits
  - FR2 high bands (above 24 GHz)
    - Provides high capacities for extreme broadband use cases
    - Limited coverage → relatively more suited for small cell deployments

Source: Qualcomm

# 5G NR Duplexing arrangement

- Low and mid bands operate in TDD or FDD
- High bands will be TDD

| 3GPP freq. range | Corresponding frequency range | Duplexing in different bands |
|---|---|---|
| FR1 | 450-6000 MHz | FDD or TDD |
| FR2 | 24250-52600 MHz | TDD |

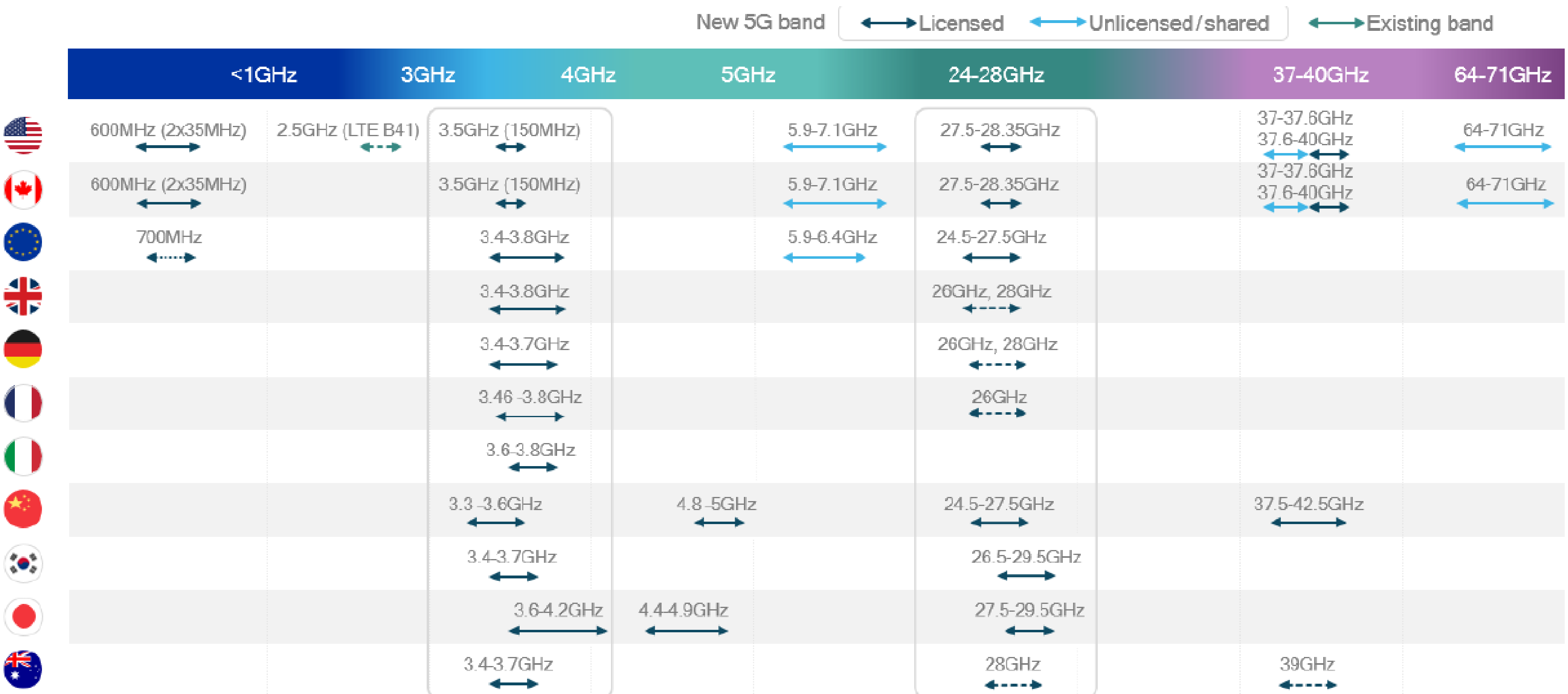
*Table 3: FR2 bands*

| NR operating band | Uplink (UL) and downlink (DL) | Duplex mode |
|---|---|---|
| n257 | 26500–29500 MHz | TDD |
| n258 | 24250–27500 MHz | TDD |
| n260 | 37000–40000 MHz | TDD |
| n261 | 27500–28350 MHz | TDD |

Source: GSA, 2018

# 5G NR Frequency Bands

- Both licensed and unlicensed bands considered in various regions
  - Regional variations noted

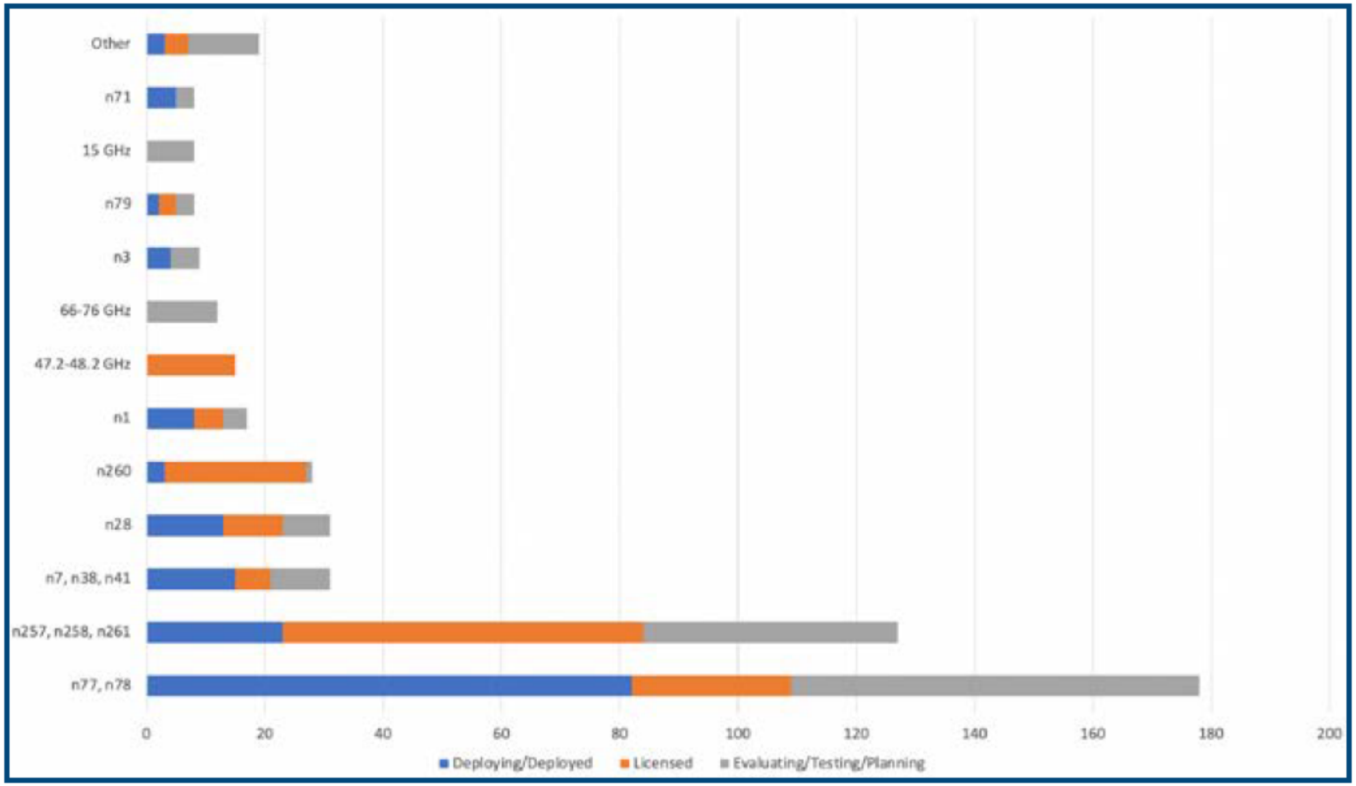



Source: Qualcomm

# 5G NR Frequency Bands

- 5G spectrum licenses mostly in mid bands particularly 3.5 GHz bands (n77, n78) and 26-28 GHz bands (n257, n258, n261)

Figure 1: Count of operators investing in 5G spectrum bands

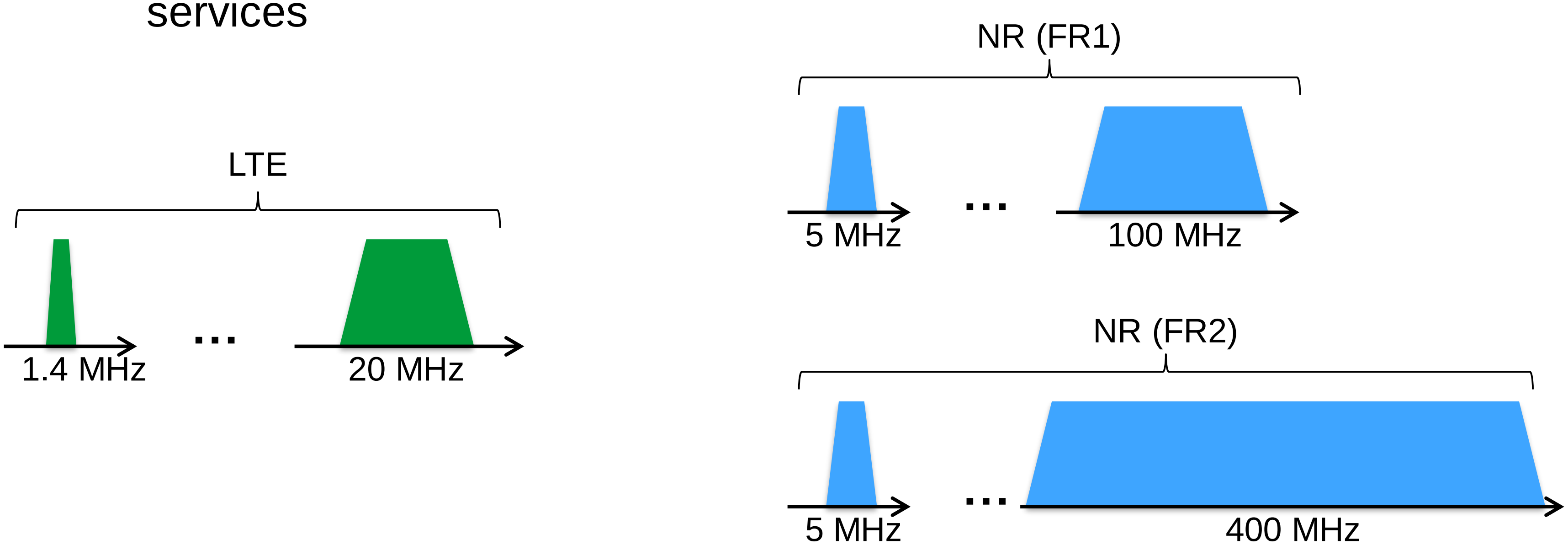



Source: GSA, September 2020

Source: Qualcomm

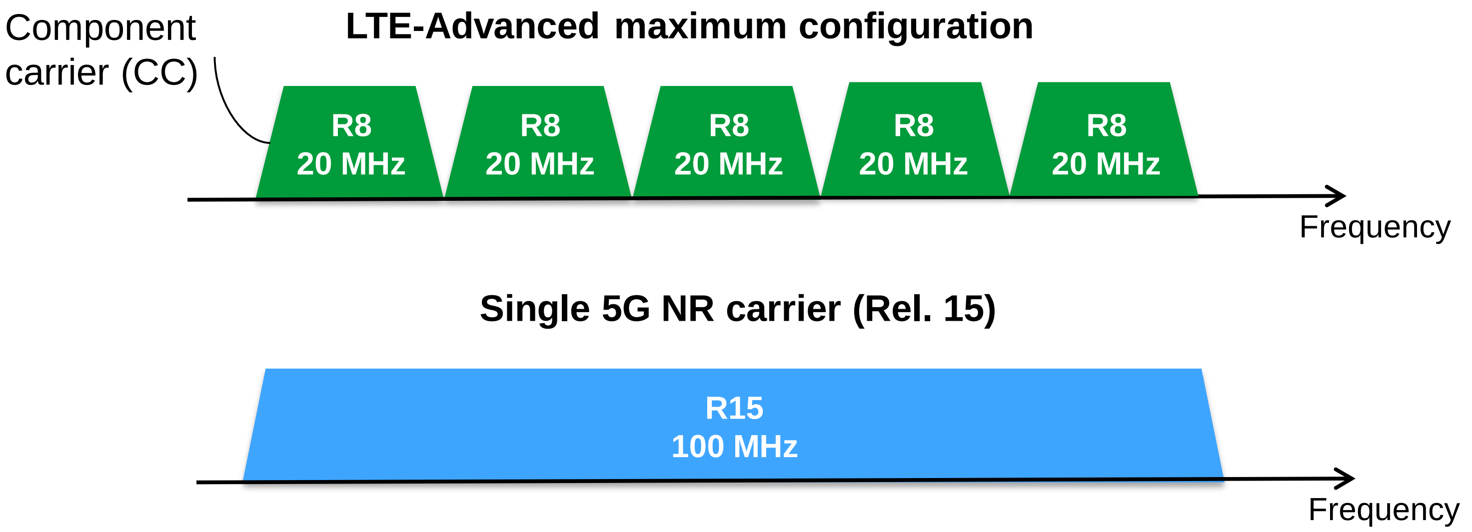
# 5G NR Carrier Bandwidths

- LTE
  - Minimum carrier bandwidth 1.4 MHz to facilitate migration of 2G bands to LTE
- NR
  - Minimum carrier bandwidth 5 MHz to enable future migration of LTE to 5G NR
  - Wider bandwidths (up to 400 MHz in high bands) for very high rate services



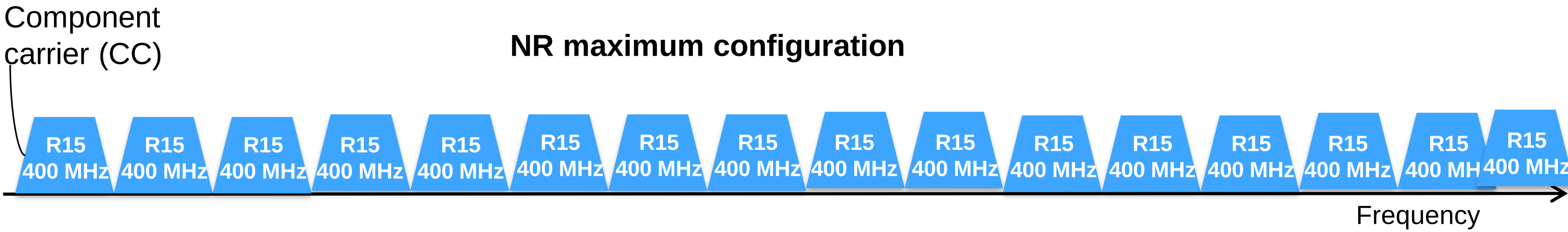
# 5G NR Carrier Bandwidths

- Use of wider bandwidths in NR more efficient that aggregated LTE carriers
  - Less common channel overhead
  - Reduced wastage of resources for guard bands between adjacent carriers (e.g. a 20 MHz LTE component carrier may use up to 2 MHz on guard bands)



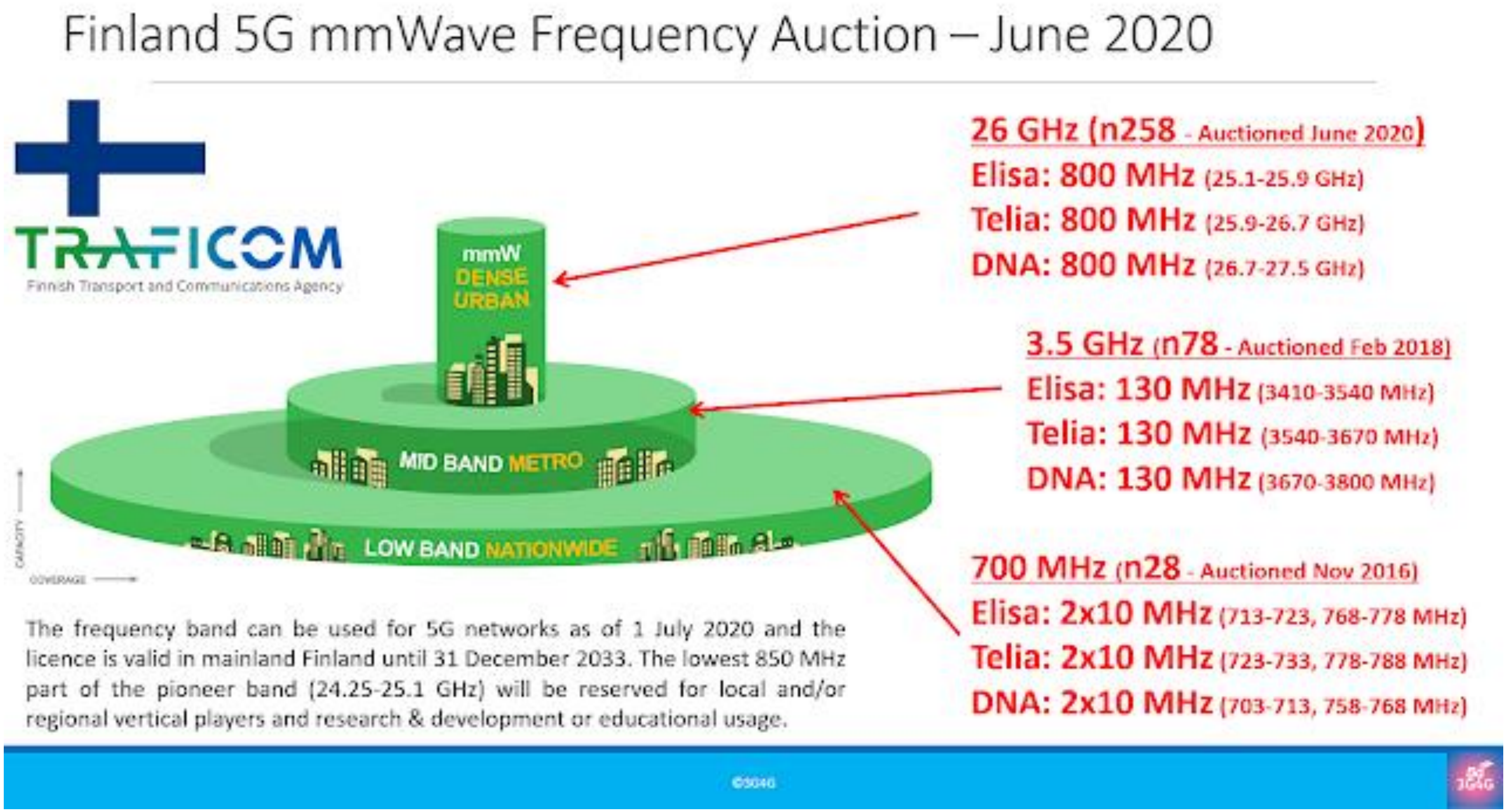
# 5G NR Carrier Aggregation

- 5G NR Carrier Aggregation allows combining up to 16 5G NR component carriers (16x400 MHz = 6.4 GHz)
  - In practice it is still challenging to identify bands with such spectrum resources



# 5G NR Carrier Bandwidths

- Low/mid/high-band 5G spectrum allocations in Finland
  - Some local test licenses also provided (e.g. Aalto holds a license for 60 MHz spectrum in these bands for Aalto 5G test network)

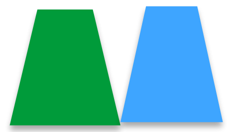


# Migration or Coexistence of LTE and NR

- A number of potential scenarios for spectrum allocation when migrating to (or coexisting with) NR

LTE only

LTE-NR coexistence

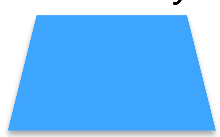


- Split spectrum and maintain separate carriers between LTE and NR
- Simple implementation for coexistence but capacity limited and suboptimal load balancing

LTE-NR coexistence

- Dynamic sharing of spectrum between LTE and NR due commonalities in frame structure
- Allows load to balanced according to evolving NR adoption trends

NR only



- Complete refarming of LTE spectrum to NR
- Long term solution when operator see no need to continue supporting LTE UEs

# 5G NR Numerology

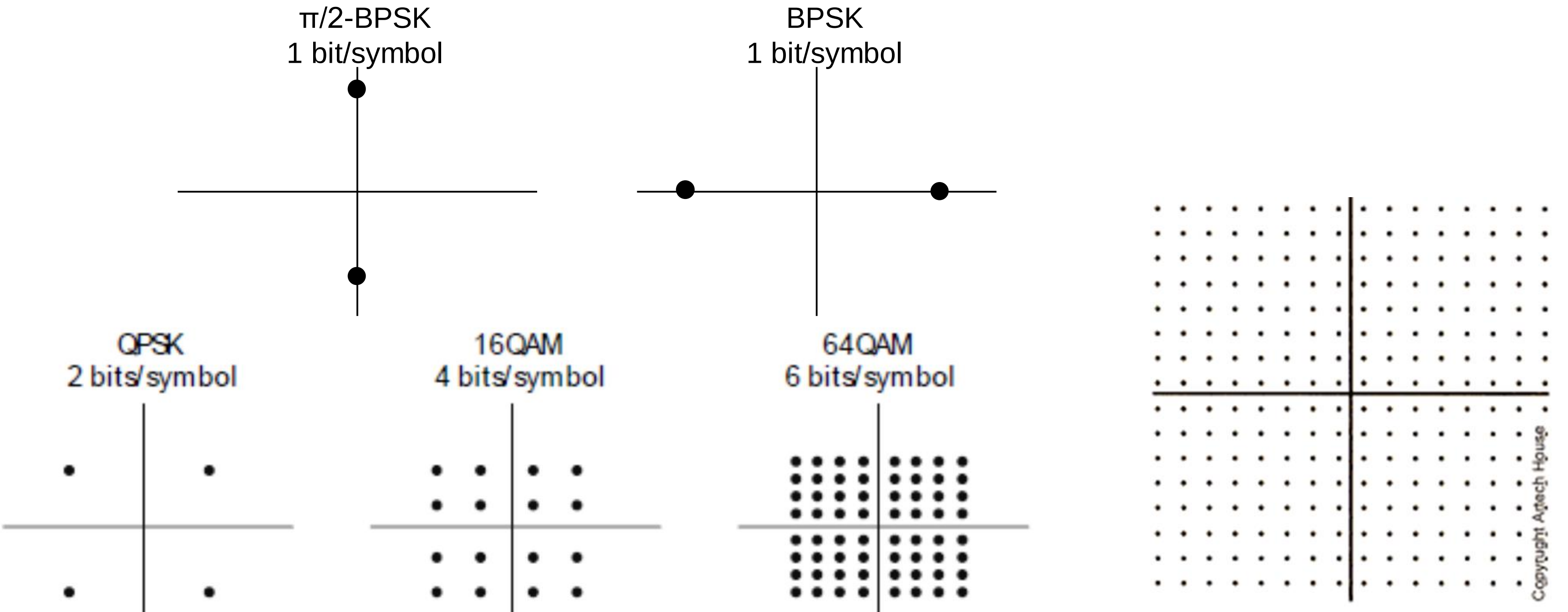
# 5G NR Multiple Access Schemes

- LTE
  - OFDM in downlink
  - SC-FDMA in uplink

- 5G NR
  - OFDM in downlink
  - Either OFDM or DFT spread OFDM (DFT-s-OFDM) in uplink
    - DFT = Discrete Fourier Transform
    - Essentially DFT-s-OFDM is same as SC-FDMA and motivation for use is the same (→ reduce PAPR for improved device power efficiency or battery life)

# NR Modulation

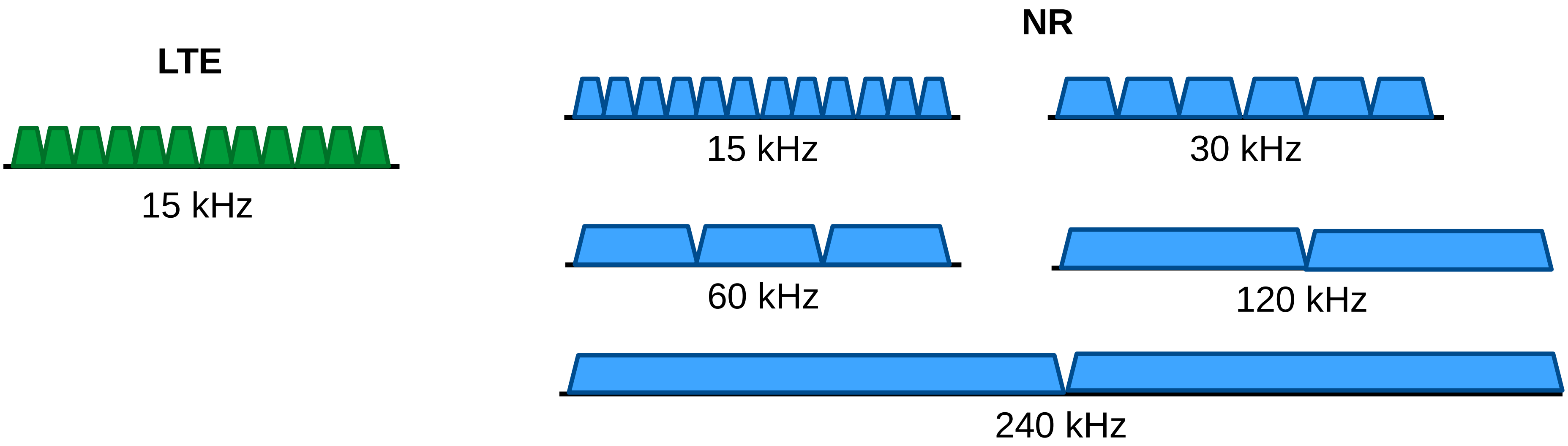
- In NR, π/2-BPSK, BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM modulations are supported for the user plane channels
  - π/2-BPSK introduced in UL as scheme for enhanced power-amplifier efficiency (low PAPR) at lower data rates (e.g. for mMTC devices)
  - BPSK introduced for one format of the uplink control channel




Ideal 256 QAM constellation

# 5G NR Numerology

- LTE
  - Single numerology → 15 kHz subcarrier spacing (which in turn fixes durations of OFDM symbols, slots etc.)
- 5G NR
  - Flexible numerology with different subcarrier spacing possible ($2^{\mu}\times 15$ kHz) → 15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz
  - Symbol lengths is also scaled accordingly → wider spacing results in shorter symbol durations



# 5G NR Numerology

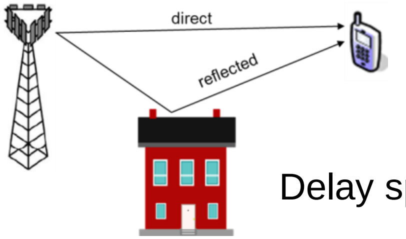
- Lower numerology preferred in low and mid bands (FR1)
  - To support larger cell areas (more delay spread tolerated) → same motivation we had with LTE
- Higher numerology preferred in high bands (FR2)
  - Needed in high bands because Doppler spread (spectral broadening) is higher and frequency/phase errors more severe → interference between subcarriers
  - Shorter symbol durations desirable for low latency applications

| 3GPP freq. range | Corresponding frequency range | Numerology (subcarrier spacing) |
|---|---|---|
| FR1 | 450-6000 MHz | 15 kHz, 30 kHz, 60 kHz |
| FR2 | 24250-52600 MHz | 60 kHz, 120 kHz, 240 kHz |

$$f_m = \frac{v f_c}{c}$$

$f_m$ = Doppler spread
$f_c$ = Carrier frequency
$c$ = Speed of light
$v$ = Moving speed

Doppler spread




Delay spread

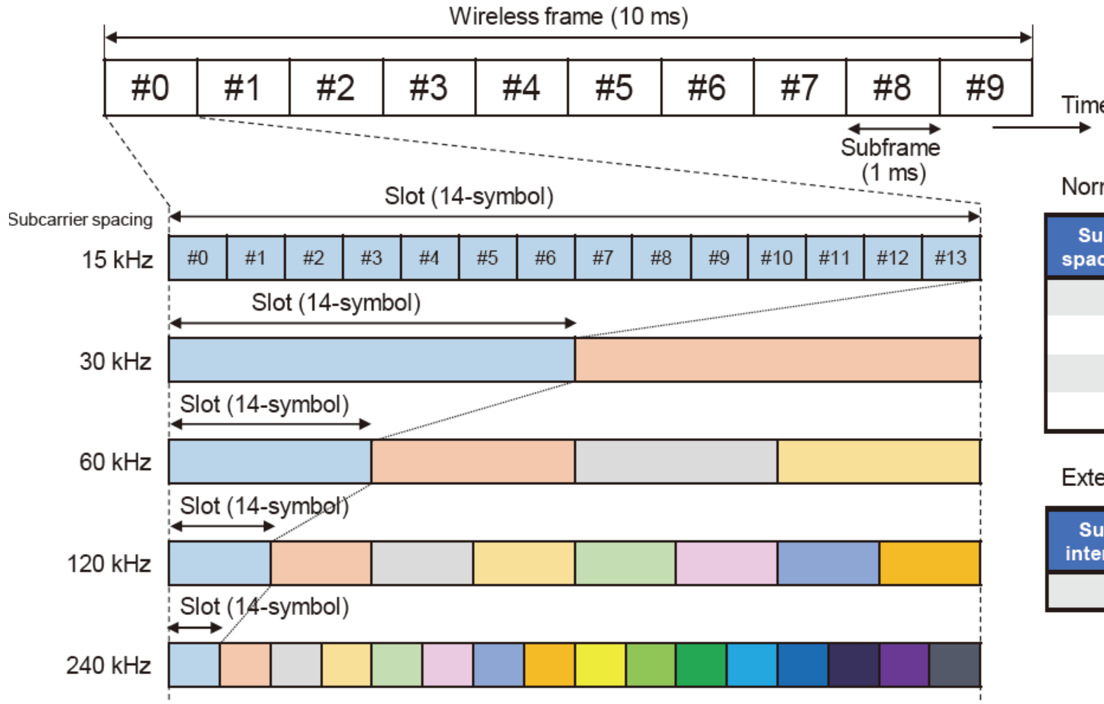
# 5G NR Radio Frame Structure

| Attributes | LTE radio frame | NR radio frame |
|---|---|---|
| **Frame length** | 10 ms | 10 ms |
| **Subframe length** | 1 ms | 1 ms |
| **Slots per subframe** | Fixed number of slots in subframe:<br>2 slots each 0.5 ms | Slot number of varies with numerology:<br>If $\Delta f$ = 15 kHz, 1 slot of 1 ms<br>If $\Delta f$ = 30 kHz, 2 slots each 0.5 ms<br>If $\Delta f$ = 60 kHz, 4 slots each 0.25 ms<br>If $\Delta f$ = 120 kHz, 8 slots each 0.125 ms<br>If $\Delta f$ = 240 kHz, 16 slots each 0.0625 ms |
| **OFDM symbols per slot** | 7 symbols per slot (normal CP)<br>6 symbols per slot (extended CP) | *Standard slot*: 14 symbols per slot (normal CP), 12 symbols per slot (extended CP)<br><br>*Mini slots*: 7, 4 or 2 symbols per slot |
| **OFDM symbol duration** | Fixed at 66.67 µs (= 1/15 kHz) | Duration varies with numerology:<br>= $1/\Delta f$ |
| **Cyclic Prefix (CP) duration** | 4.7 µs 5.2 µs (normal CP)<br>16.7 µs (extended CP) | Duration varies with numerology:<br>= 4.7 µs / $m$ whereby $\Delta f = 2^m$ x 15 kHz |



CP: Cyclic Prefix
$\Delta f$ : Subcarrier spacing

# 5G NR Radio Frame Structure




Normal cyclic prefix

| Subcarrier spacing [kHz] | No. of symbols per slot | No. of slots per subframe | No. of subframes per frame |
|---|---|---|---|
| 15 | 14 | 1 | 10 |
| 30 | 14 | 2 | 10 |
| 60 | 14 | 4 | 10 |
| 120 | 14 | 8 | 10 |

Extended cyclic prefix

| Subcarrier interval [kHz] | No. of symbols per slot | No. of slots per subframe | No. of subframes per frame |
|---|---|---|---|
| 60 | 12 | 4 | 10 |

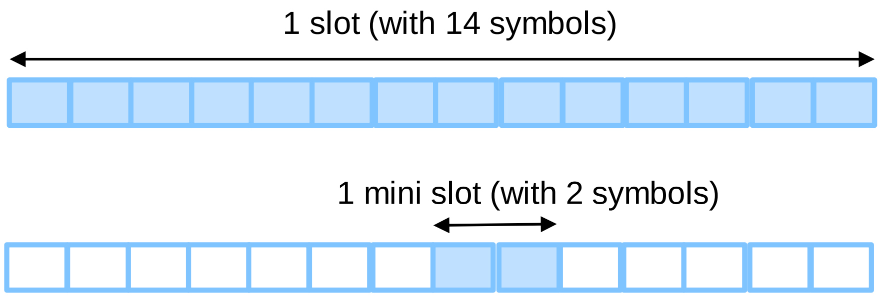
Source: NTT Docomo technical journal, Jan 2019



CP: Cyclic Prefix
$\Delta f$ : Subcarrier spacing

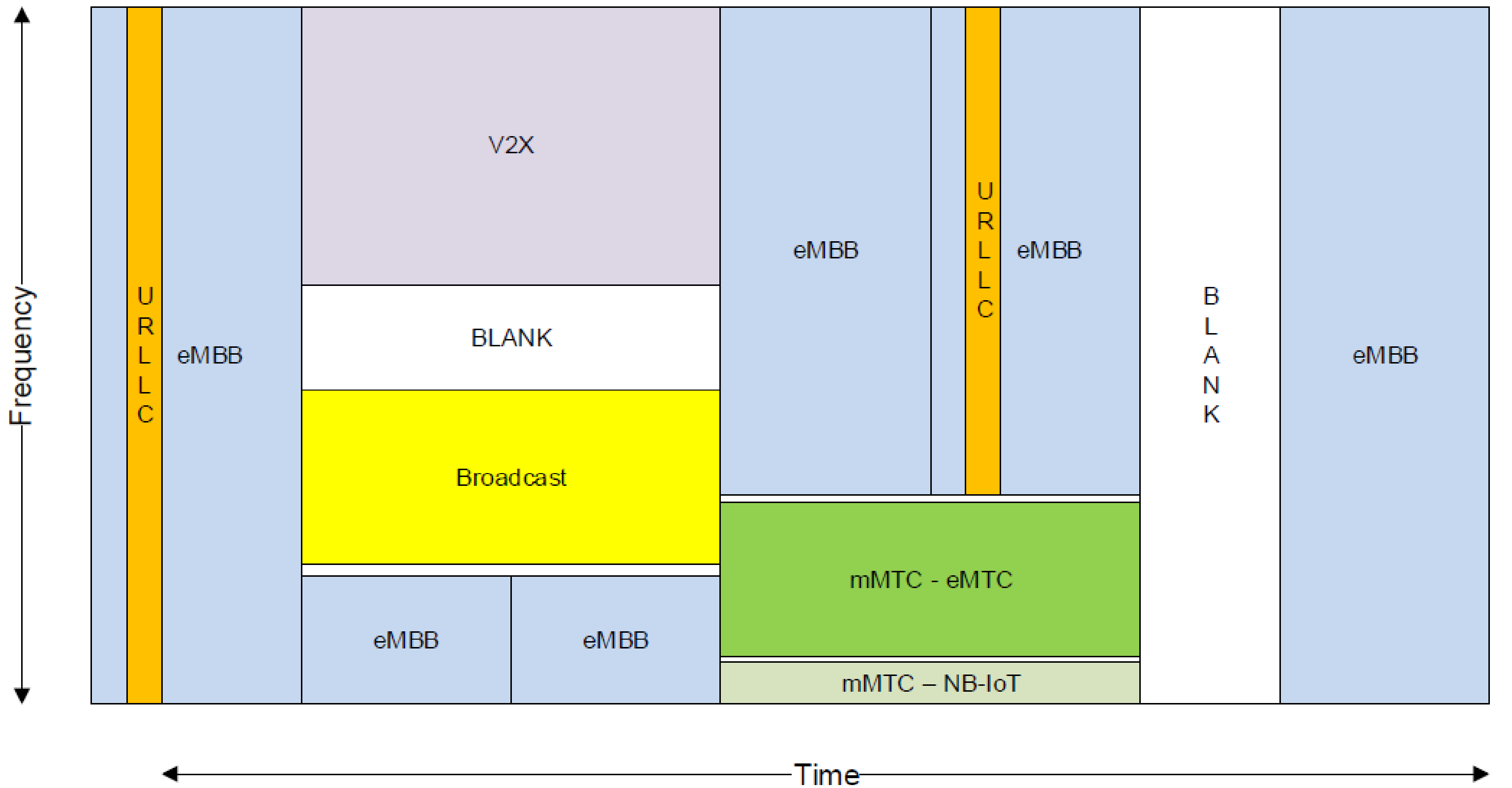
# 5G NR Radio Frame Structure

- Recall 5G NR specifies mini slots of 7, 4 or 2 symbols per slot
- Mini slot transmissions may begin any time (immediately) within a standard slot → no need to wait for the beginning of the standard slot
  - Contributes to reduced latency for URLLC
  - Enables fast retransmission in case of errors → enhances reliability



# 5G NR Physical Resources

- Flexible numerology in NR provides framework for more effective support of different services and QoS requirements
  - Flexible radio resource allocation in time-frequency grid




Source: Nokia, 2017

# Massive MIMO Enhancements

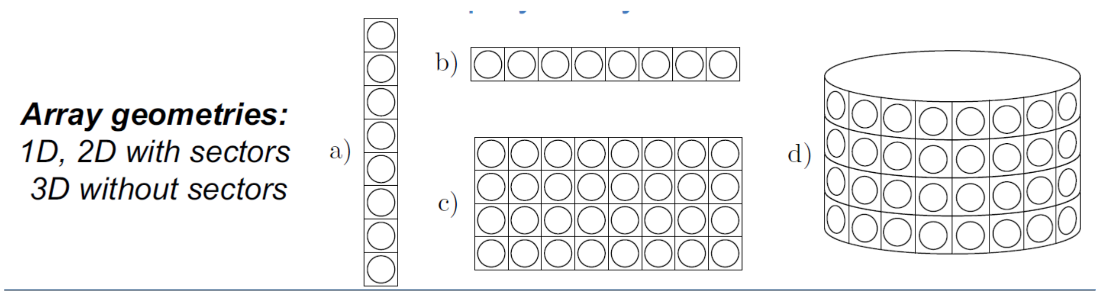
# Massive MIMO for 5G NR

- Extension of the MIMO configurations to antenna arrays with large number of controllable antennas (16 or more antenna ports in NR)

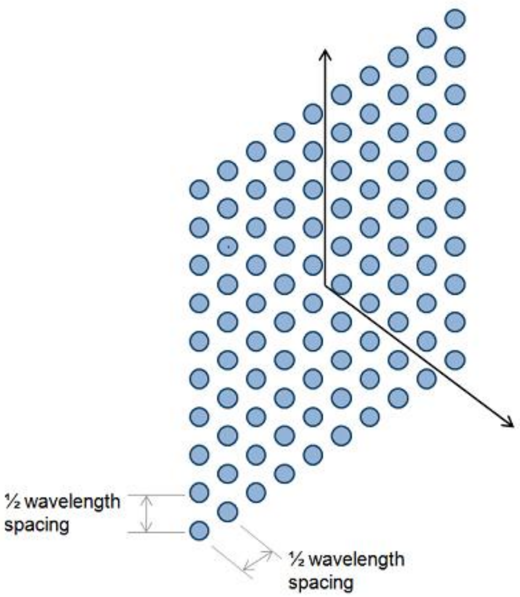
| 3GPP freq. range | Corresponding frequency range | Need and benefit for Massive MIMO |
|---|---|---|
| FR1 | 450-6000 MHz | - Interference-limited (SINR limit)<br>- Spectrum scarcity (capacity limitation)<br>- Benefit: Improved spectral efficiency |
| FR2 | 24250-52600 MHz | - High path loss (coverage-limited)<br>- Stringent line-of-sight requirements<br>- Benefit: Beamforming increases signal strength by focusing to individual UEs |

# Massive MIMO for 5G NR

- Antenna array technologies have become more technically and commercially feasible
  - Antenna array size decreases with increased carrier frequency e.g. antenna arrays in FR2 frequencies could be a hundredth of corresponding FR1 array
  - More antennas enables increased directivity (*see example in next slide*)



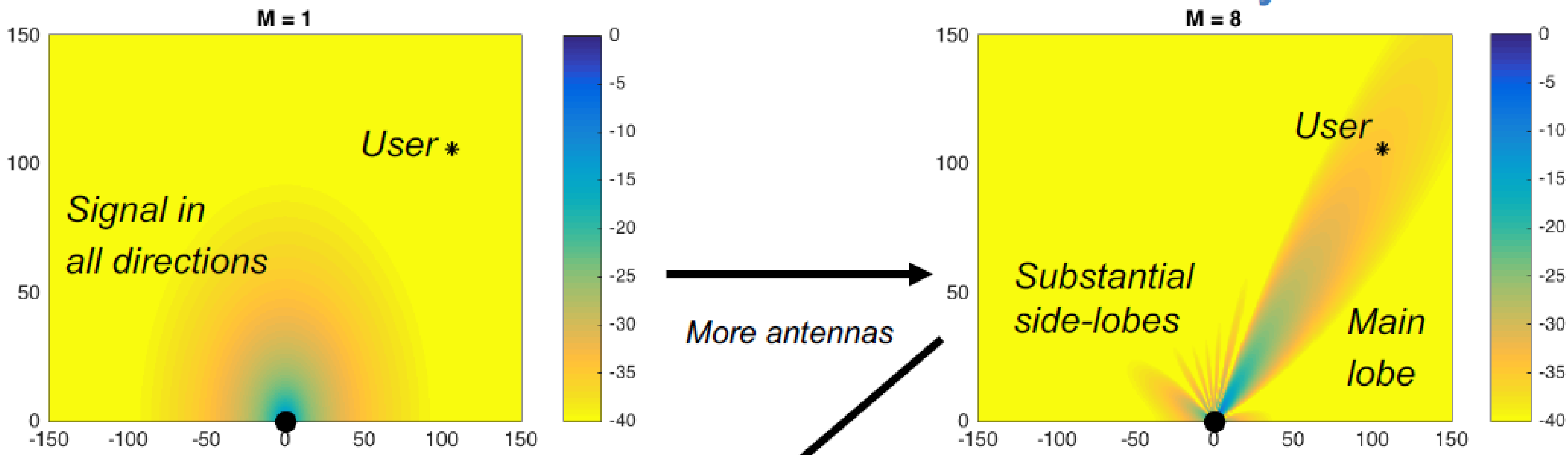

Source: E. Björnson, Massive MIMO for 5G: How Big Can it Get?

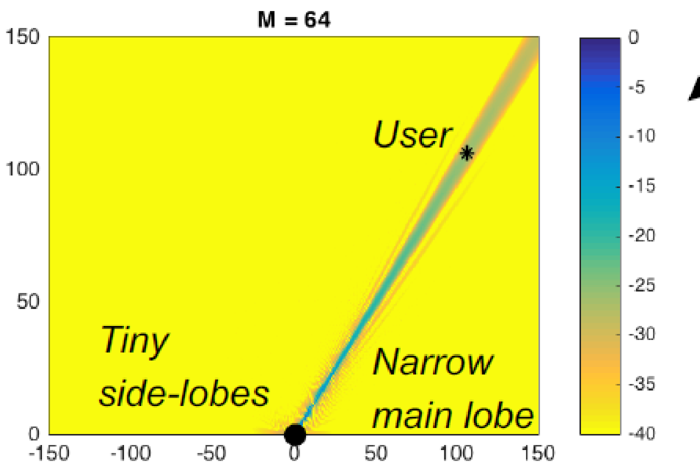



Source: Mathworks

# Massive MIMO for 5G NR

## More Antennas → More Directivity



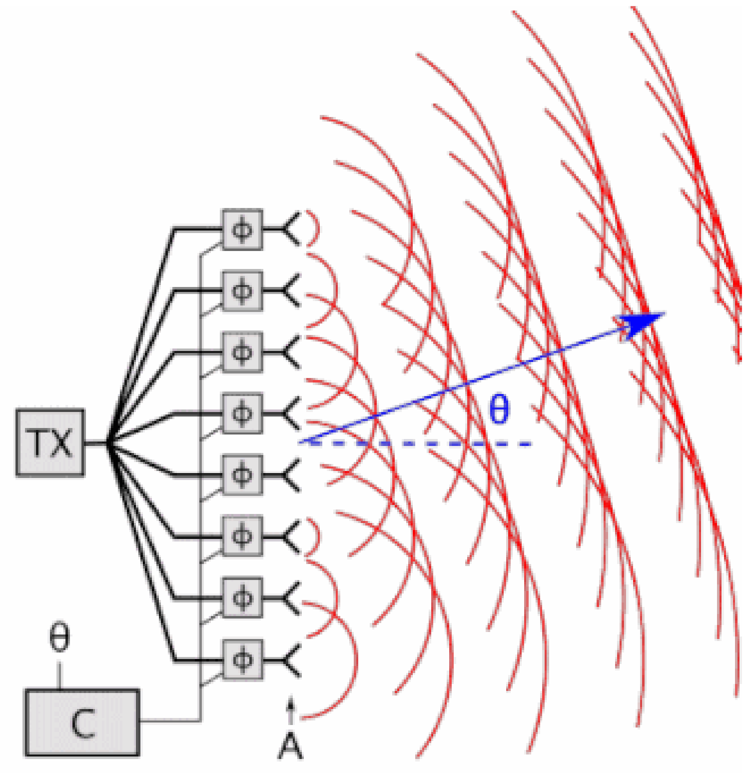

**Same transmit power**
- *M* base station antennas
- Color indicates pathloss in dB
- Main lobe focused at user

**More antennas**
- Array gain: 10 $\log_{10}(M)$ larger at user
- Less leakage in other directions

Source: E. Björnson, Massive MIMO for 5G: How Big Can it Get?

# Beamforming basics

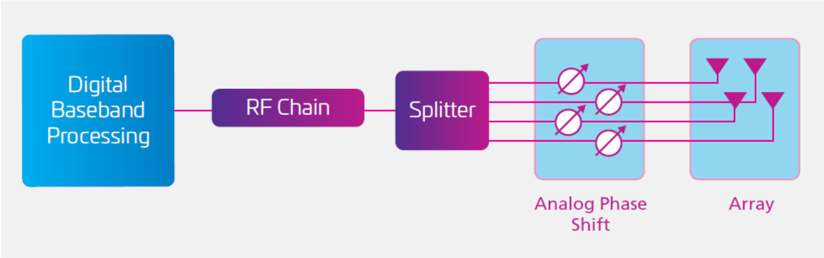
- Phase shifting operation applied on different antenna elements in an array allows to point or steer beam towards target users
  - Constructive/destructive combination of individual beams
- Each antenna element in an array has its own radiation pattern but overall beamforming effect of entire array depends on the:
  - Array size
  - Antenna element spacing
  - Antenna elements' signal phase shifts and amplitude variation



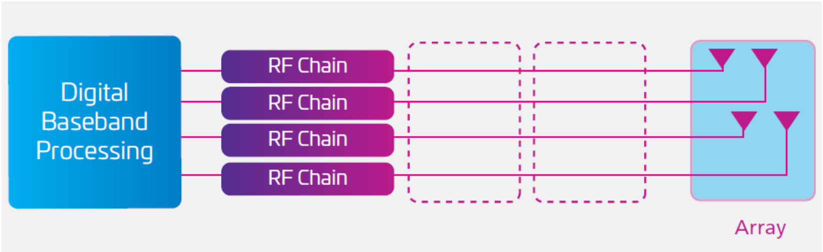

Source: ComScope

# Beamforming basics

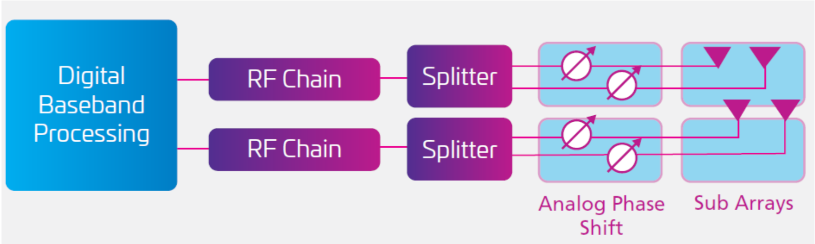
- Three possible ways of implementing beamformers (phase shifters)
- Analog beamforming
  - Uses a single common RF source split among multiple antenna elements.
  - The beam is controlled by adjusting analog phase shifters along the RF path
- Digital beamforming
  - Each antenna has a dedicated RF signal and path.
  - Phases and amplitudes are digitally controlled by baseband processing.
  - Provides the best beam control ☺
  - High power consumption and signaling overheads due to many RF chains ☹
- Hybrid beamforming
  - Combines features of analog and digital beamforming.
  - Digitally controlled RF chains, splitters and analog phase shifters.




Analog beamforming




Digital beamforming

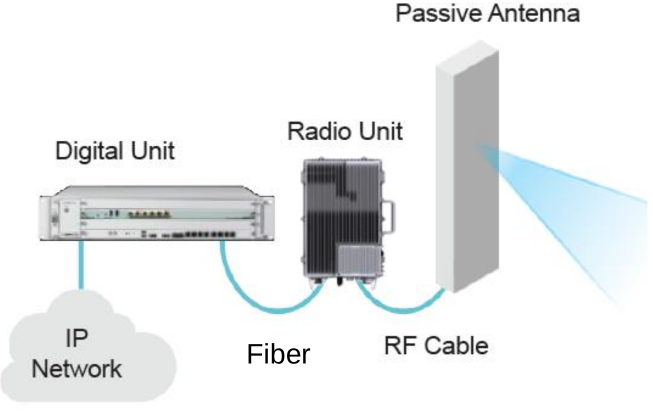



Hybrid beamforming

Source: ComScope

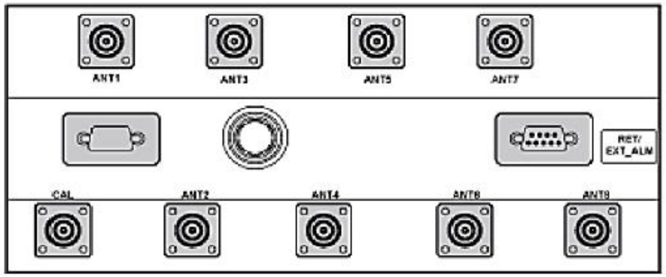
# Passive vs Active Antennas

- Passive antennas
  - RF electronics deployed in separate box
  - Need to have separate RF cables for each antenna port
  - Number of cables increases with MIMO antenna ports → more bulky, many failure points etc. ☹




Source: Samsung

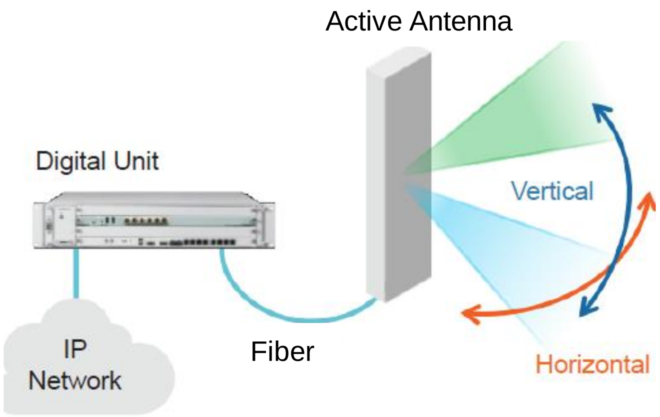
Sprint/SAMSUNG 8T8R installation



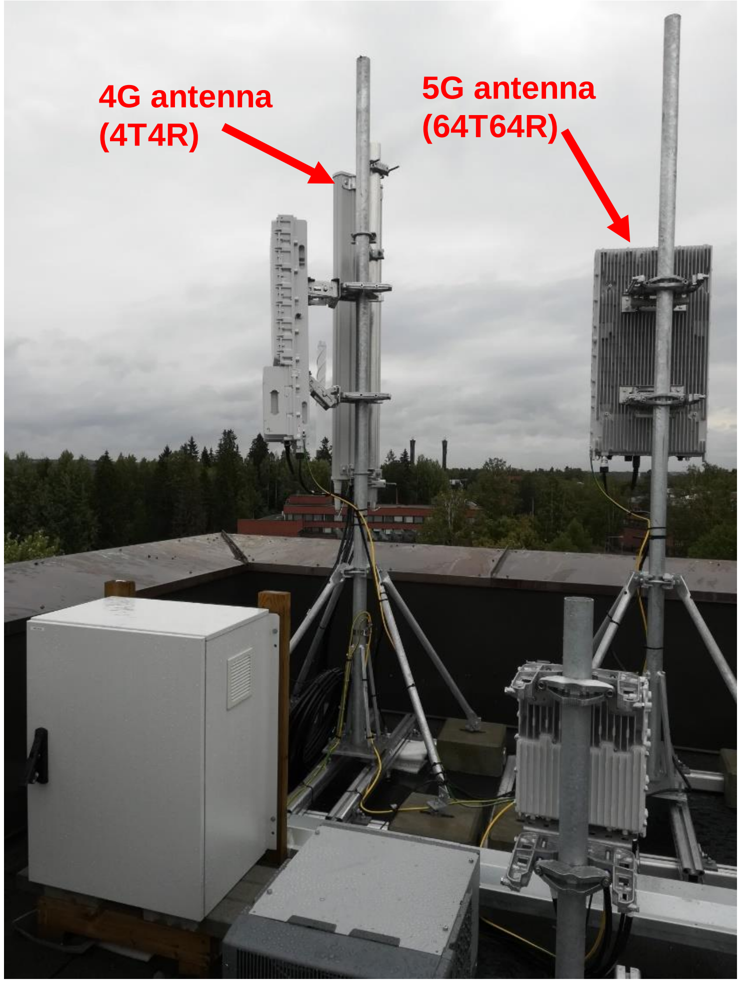

Source: ComScope

# Passive vs Active Antennas

- Active antennas
  - RF electronics and antenna integrated in the same box
  - Eliminates need for multiple cables between radio unit and antenna
  - Simplifies installation and enhances reliability ☺
  - Provides scalability for massive MIMO antenna implementation ☺
  - Suitable for FR2 operation as it reduces RF losses incurred at those frequencies ☺



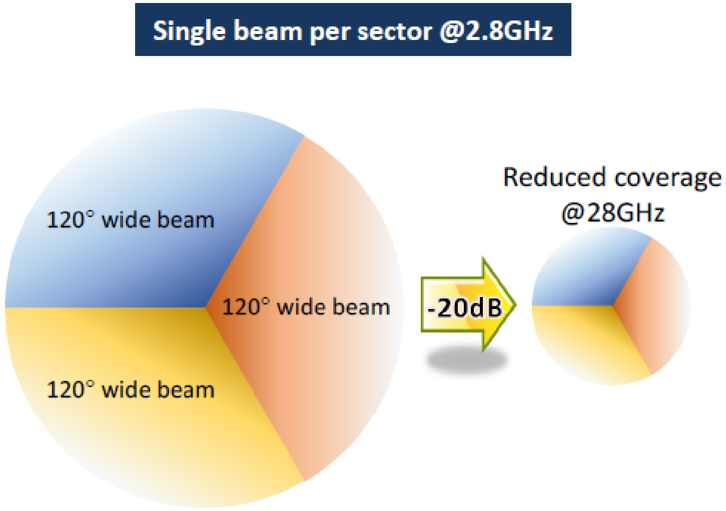

Source: Samsung

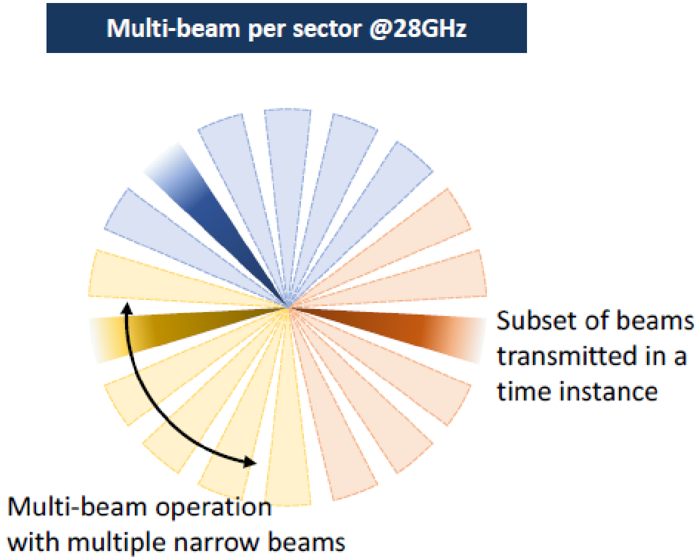



64T64R antenna from Nokia deployed at the top of Våre building in Otaniemi (Aalto 5G test network)

# Multi-beam operation

- A single beam can be used to provide wide coverage lower frequencies
  - Typical deployment scenario of LTE trisector sites
- For higher frequencies, multiple beams can be used to extend coverage

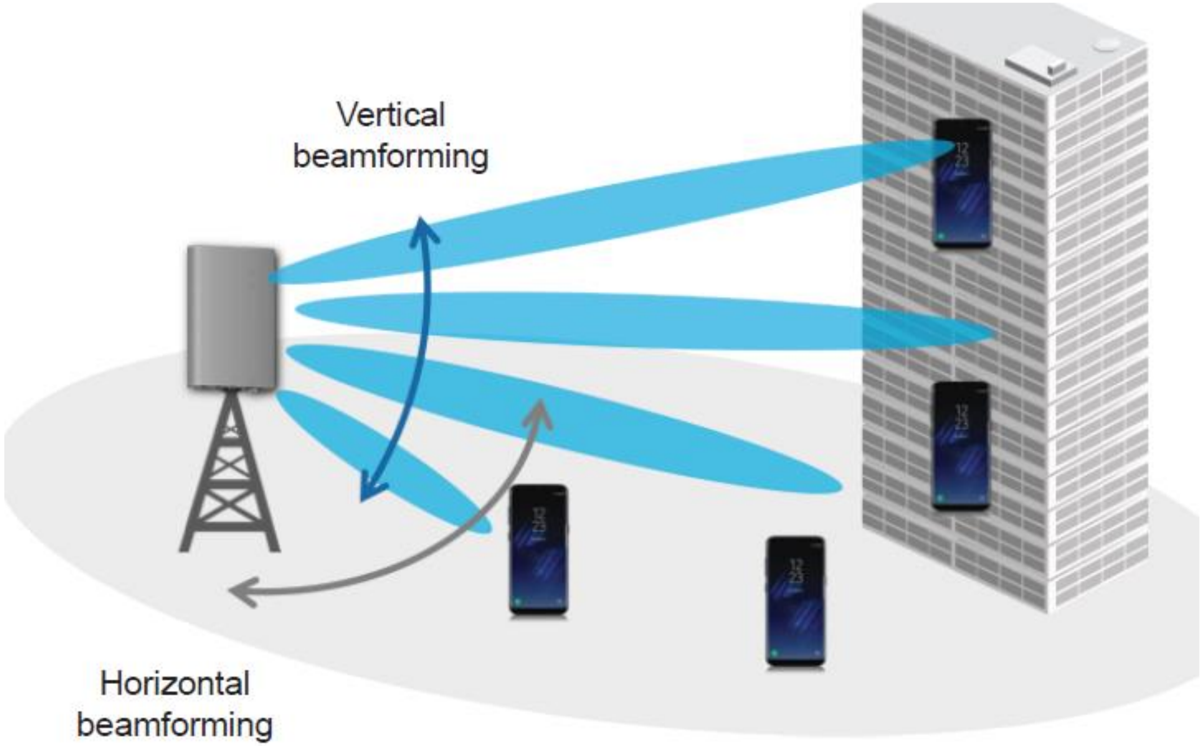



Source: 3GPP

# Multi-beam operation

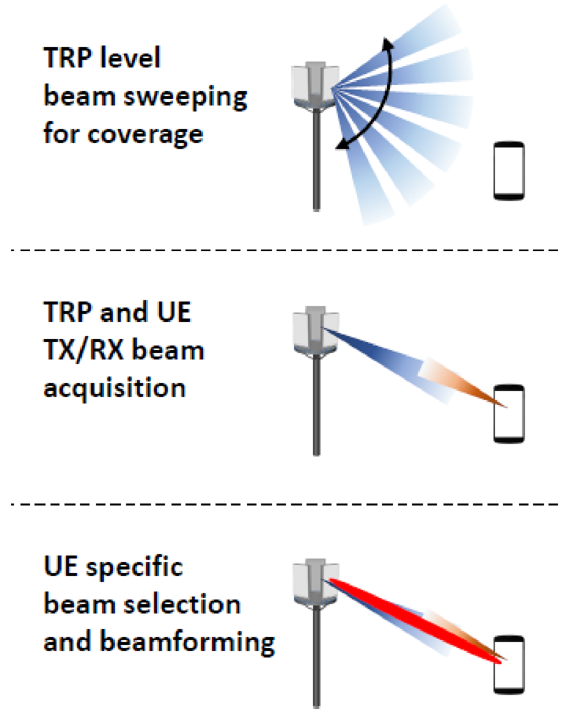
- Beamforming in 3D (both horizontal and vertical beamforming)
  - Also referred to a full-dimension MIMO

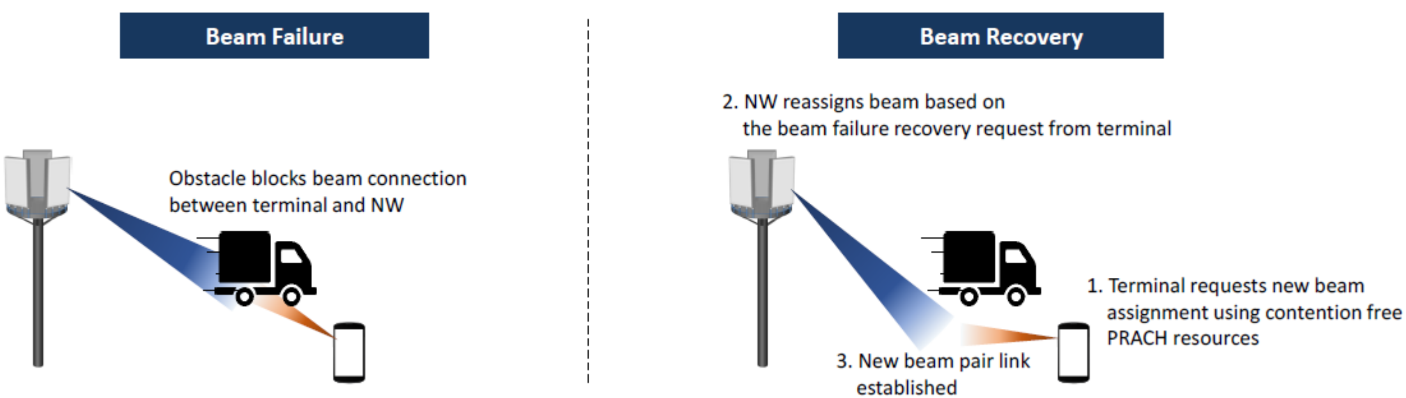



Source: Ovum

# Beam Management

- 5G NR specifications include new PHY and MAC layer procedures to support directional communications
- In 3GPP terminology, these procedures are referred to as beam management
- Beam management includes a number of distinct operations
  - Beam sweeping, beam acquisition, beamforming, beam reporting, beam recovery etc.



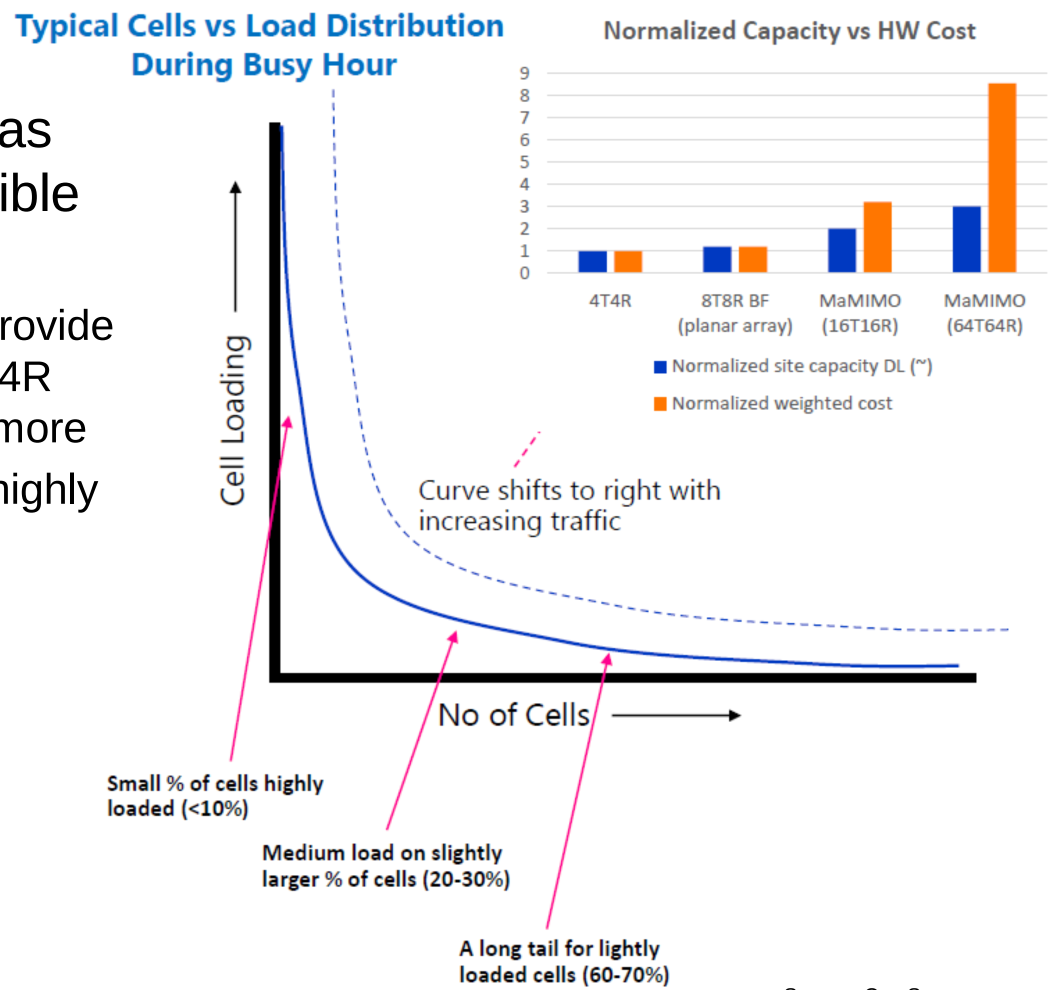




TRP = Transmission reception point

Source: 3GPP

# Techno-economical consideratons

- Higher massive MIMO antennas not always commercially sensible for all sites
  - For instance 64T64R antennas provide about 3-4x capacity gain over 4T4R antennas but cost several times more
  - Target 64T64R deployments for highly loaded cells




Source: ComScope

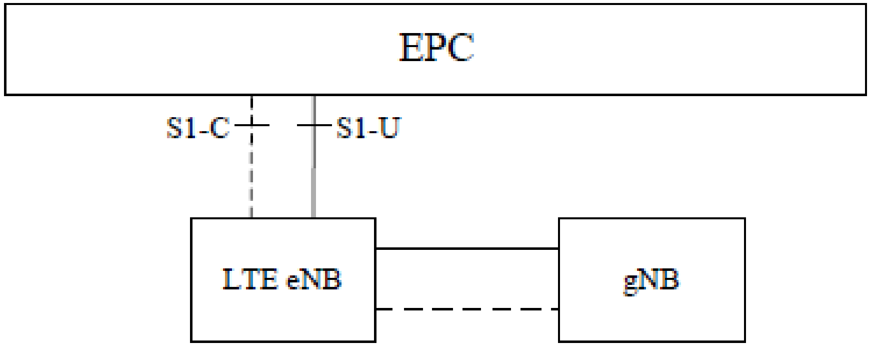
# 5G NR Architectures

# 5G NR Architectures

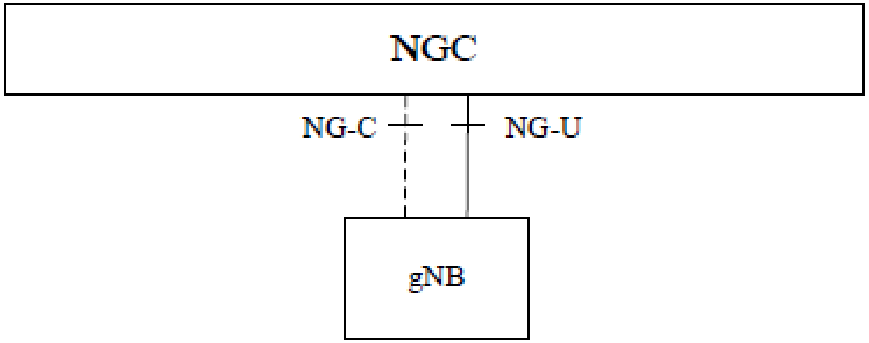
- 5G radio access network is formally referred to as Next Generation RAN (NG-RAN) in specs
- NG-RAN main component is next-generation Node B (gNB)
  - Essentially the 5G base station
- The functionalities provided by the gNB, include (but are not limited to):
  - Radio Resource Management (scheduling, admission control, radio bearer control, etc.);
  - IP and Ethernet header compression, encryption and integrity protection of data;
  - Connection setup and release;
  - Support of Network Slicing;
  - QoS Flow management and mapping to data radio bearers;
  - Radio access network sharing;
  - Dual Connectivity (with other gNB, eNB or non-3GPP access nodes).

# 5G NR Architectures

- Non-standalone architecture (NSA)
  - NR uses existing LTE RAN (eNB) and core (EPC) → Control plane functionality remains anchored in LTE
  - 5G-NR provides a complementary user plane capacity via gNB
  - Allows operator to make early 5G NR deployments
- Standalone architecture (SA)
  - 5G NR base stations (gNBs) operate independently with new 5G core network (Next Generation Core, NGC)




Non-Standalone Architecture
(Option 3)

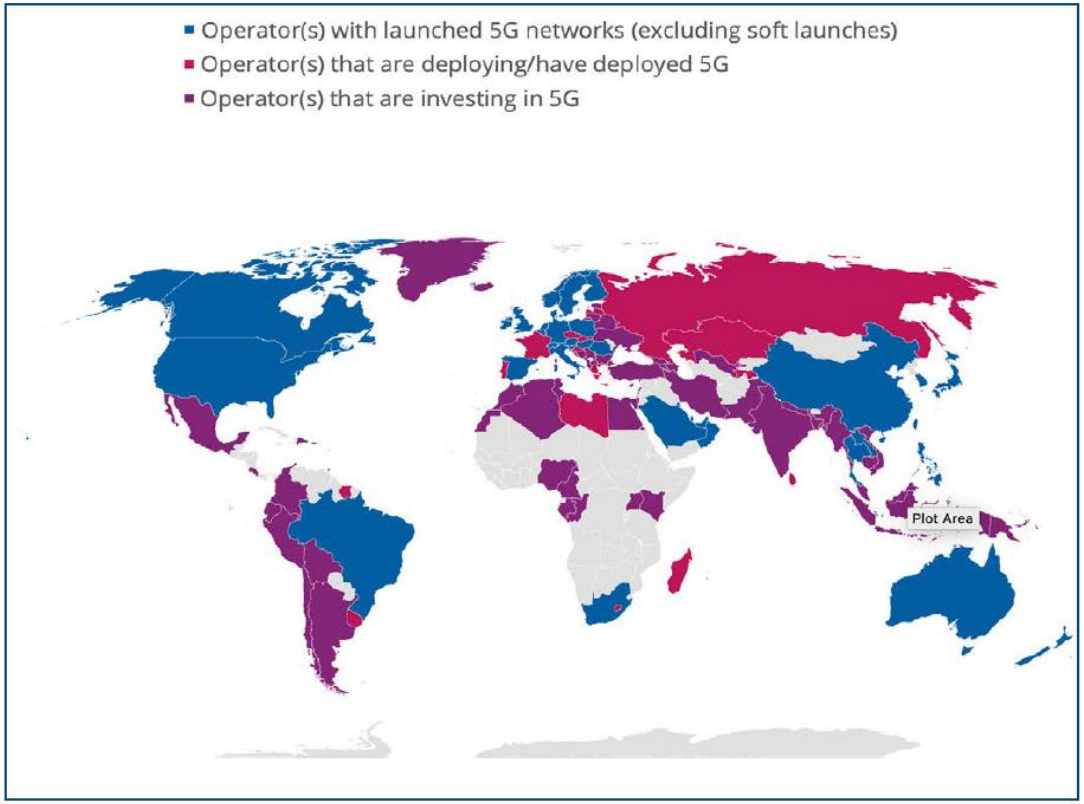



Standalone Architecture
(Option 2)

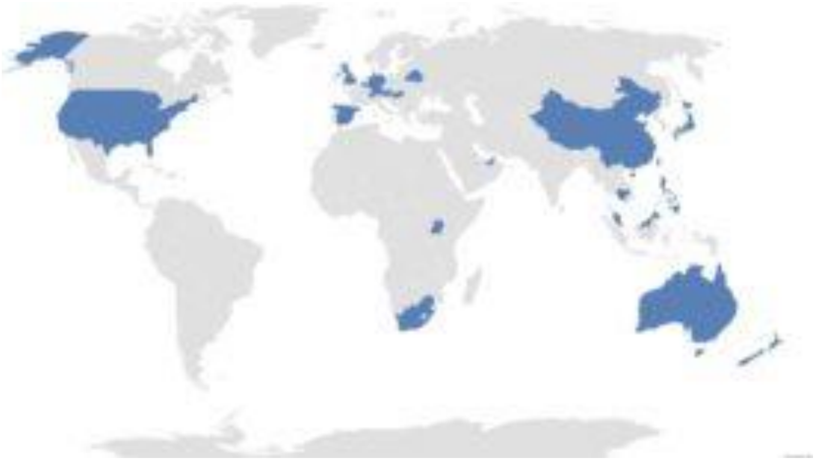
# 5G NR Architectures

- By September 2020 397 operators in 129 countries were investing in 5G
  - Majority of of those are for 5G NSA
  - GSA has identified 47 operators in 24 countries investing in 5G SA networks

Figure 3: Map of global operator investments in 5G



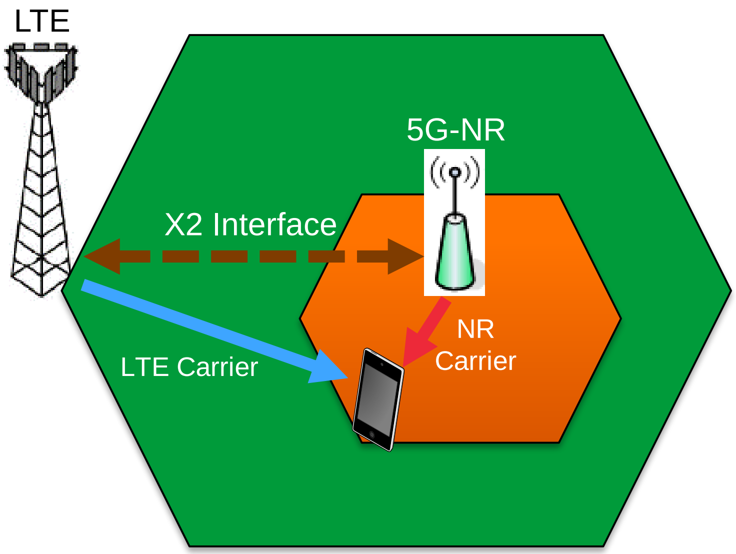

Countries with 5G SA network investments



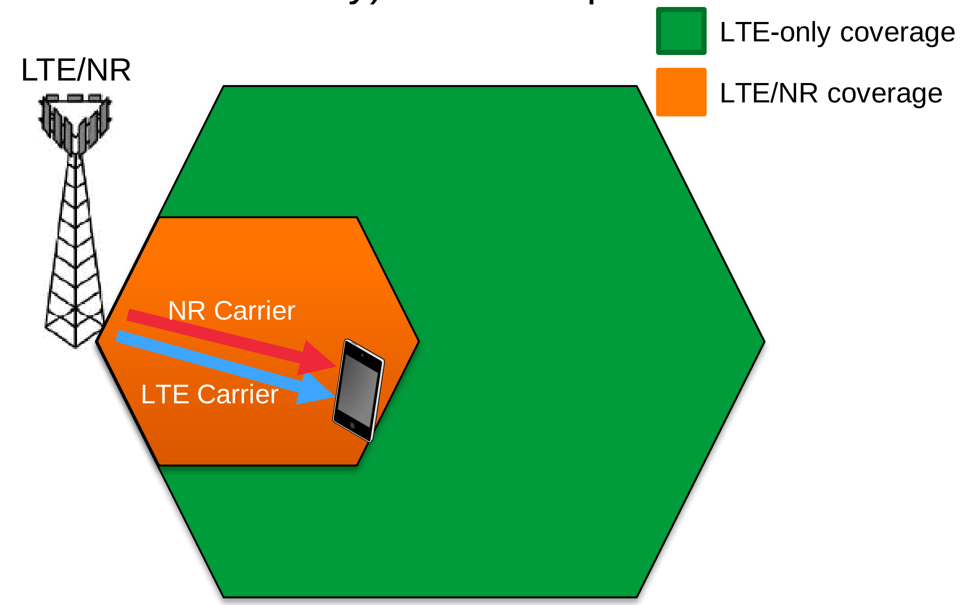
Source: GSA

# Dual Connectivity

- Possible deployment scenarios with non-standalone architecture → LTE/NR dual connectivity
  - Referred to as EN-DC (E-UTRA-NR Dual Connectivity) in 3GPP specs



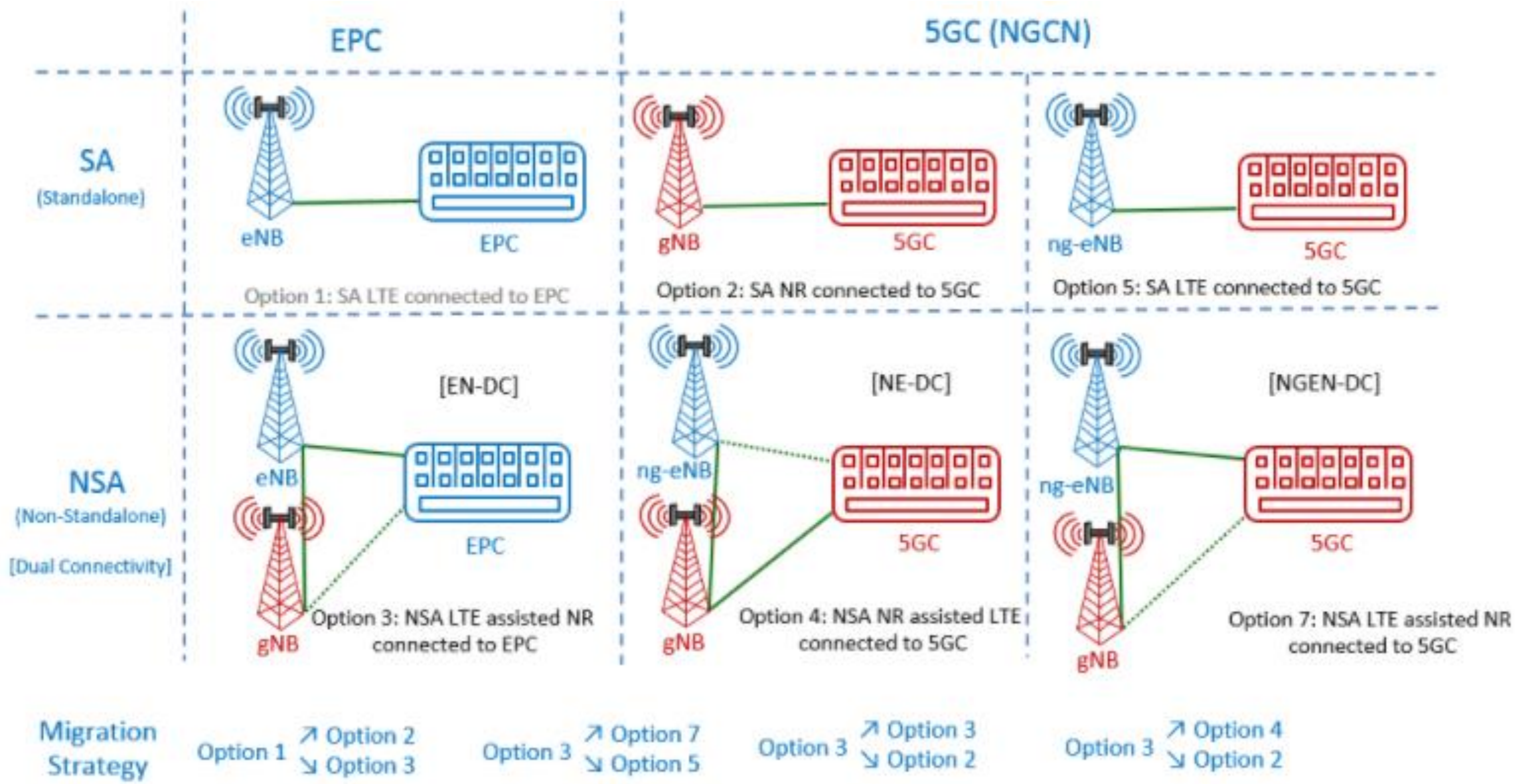

Heterogeneous deployment
- LTE macro cell and NR small cell
- LTE connection provides redundancy when UE out of NR coverage




LTE-NR co-sited deployment
- Migrational approach allowing continue service to LTE only UEs
- If high band NR, dual connectivity not available in cell edge

# Dual Connectivity

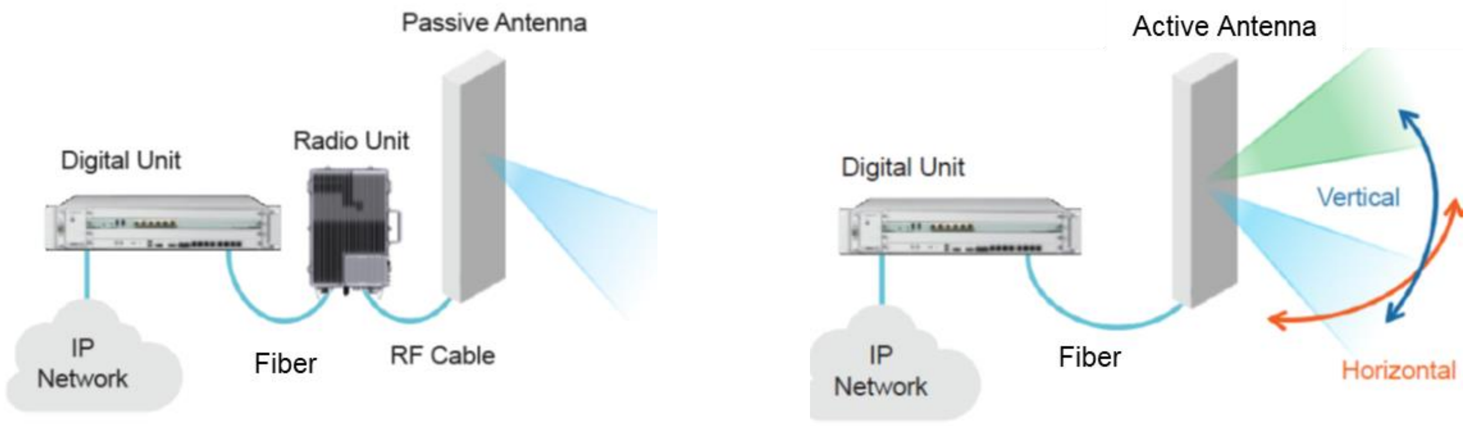
- Introduction of 5GC (NGC) platforms presents more dual connectivity options and migration strategies from 4G to 5G
  - Note: Next generation eNB = ng-eNB
  - NR-DC (NR-NR Dual Connectivity) also possible but not shown in figure below




Source: 3G4G blog

# Split Architectures

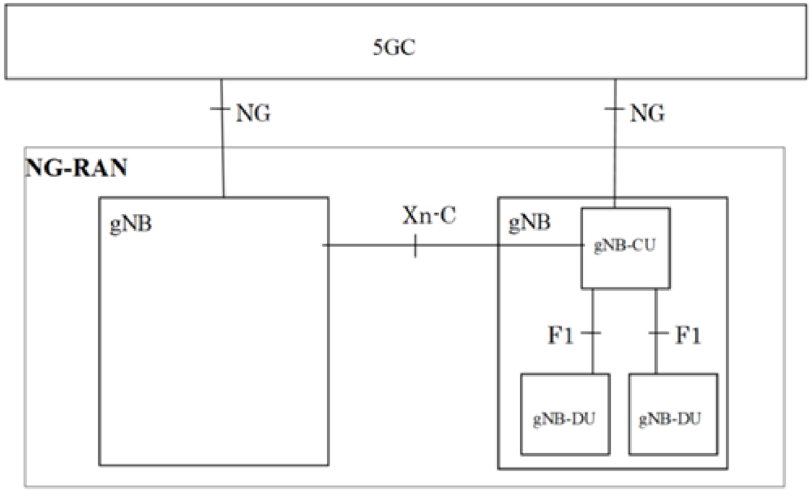
- Digital baseband processing carried out in baseband unit (BBU) typically deployed at bottom of tower or at another appropriately sheltered location
- Separation of RF and baseband functionally allows for
  - More reduced footprint on the tower and in the shelter
  - Enhancing network performance usually through high-capacity fiber connectivity between the two
- For legacy deployments the BBU serves only particular base station




Source: Samsung

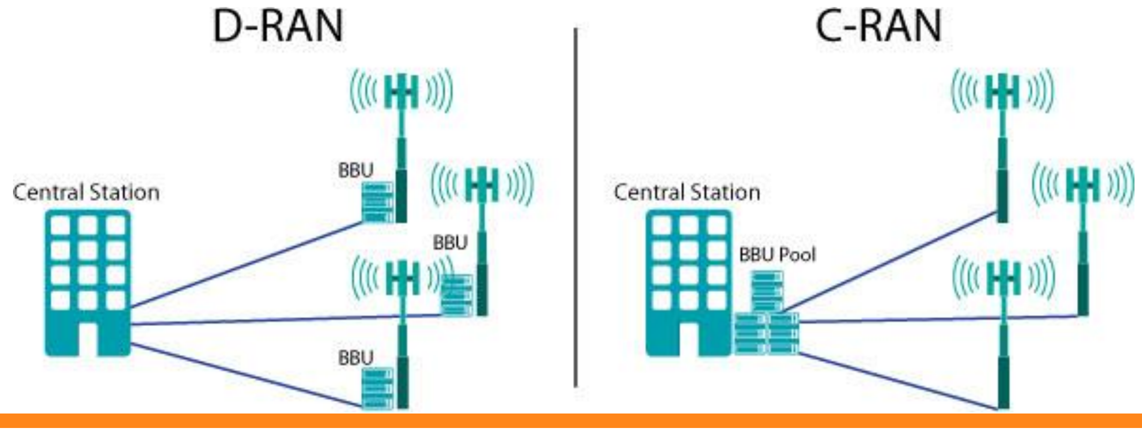
# Split Architectures

- NG-RAN architecture introduces possibility of disaggregating the baseband processing in gNB so it can be implemented in collocated or geographically separate units
  - Centralised Unit (CU): usually hosts the higher layer RRC and PDCP functions (referred to as gNB-CU in 3GPP)
  - Distributed Unit (DU): hosts the lower layer RLC, MAC and the PHY functions (referred to as gNB-DU in 3GPP)
  - Radio Unit (RU): does the RF processing (aka RRH remote radio head, or RRU, remote radio unit). May be part of DU or deployed separately.
- Multiple RUs connect to a DU, and multiple DUs connected to a centralized unit CU



# Split Architectures

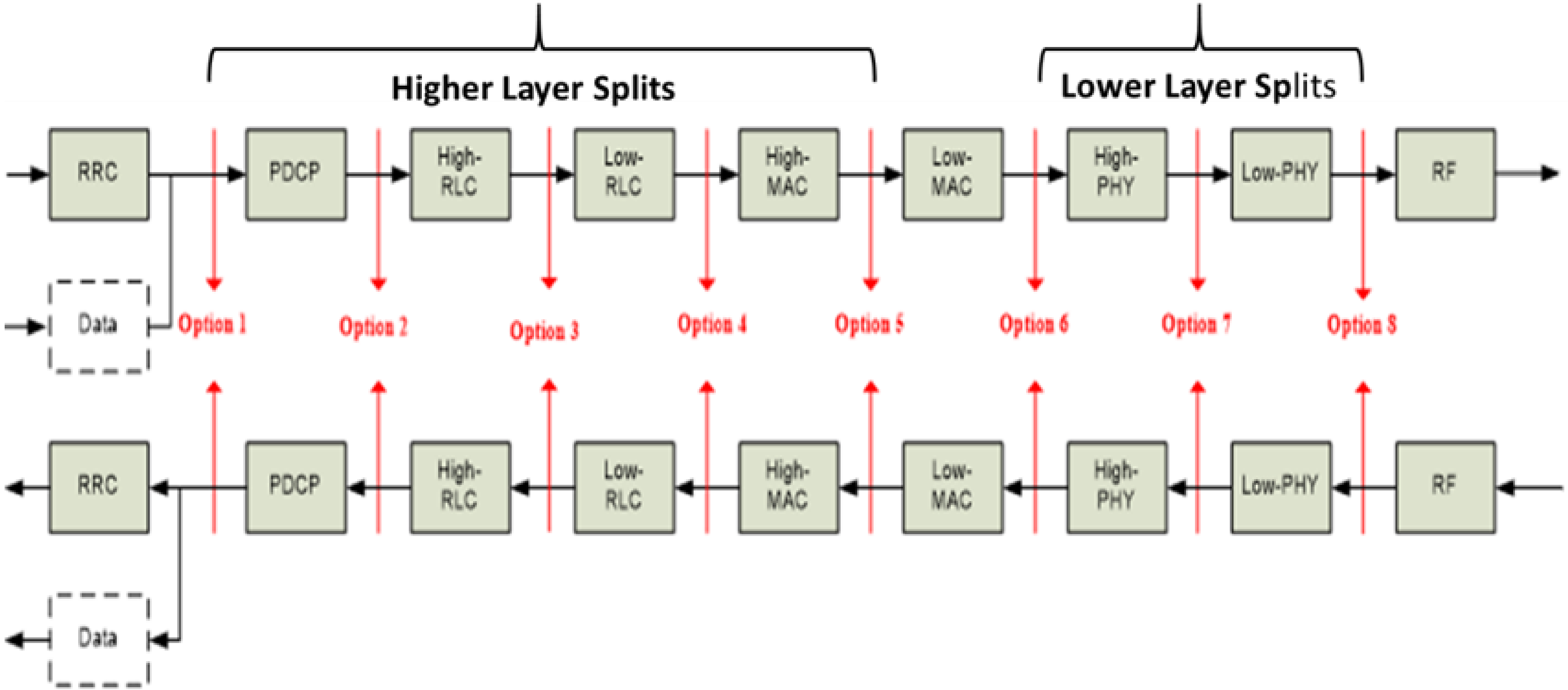
- Virtualisation of RAN functions facilitating the disaggregation
  - CU may be a shared virtual entity (software implementation) running on virtualized infrastructure in data centers
  - RU is typically dedicated hardware at the cell site
  - DU may have a combination of dedicated hardware and virtualized entity, depending on the protocol split adopted
- Motivation for disaggregated NG-RAN split architectures
  - Potential cost reduction due to low complexity radio units & BBU processor pooling (shared CU, DUs etc.)
  - Efficient operation of RUs via CUs (e.g. improved coordination for intercell interference reduction)
- Migration from distributed RAN (D-RAN) to centralised RAN (C-RAN) architectures




Source:lambdagain

# Split Architectures

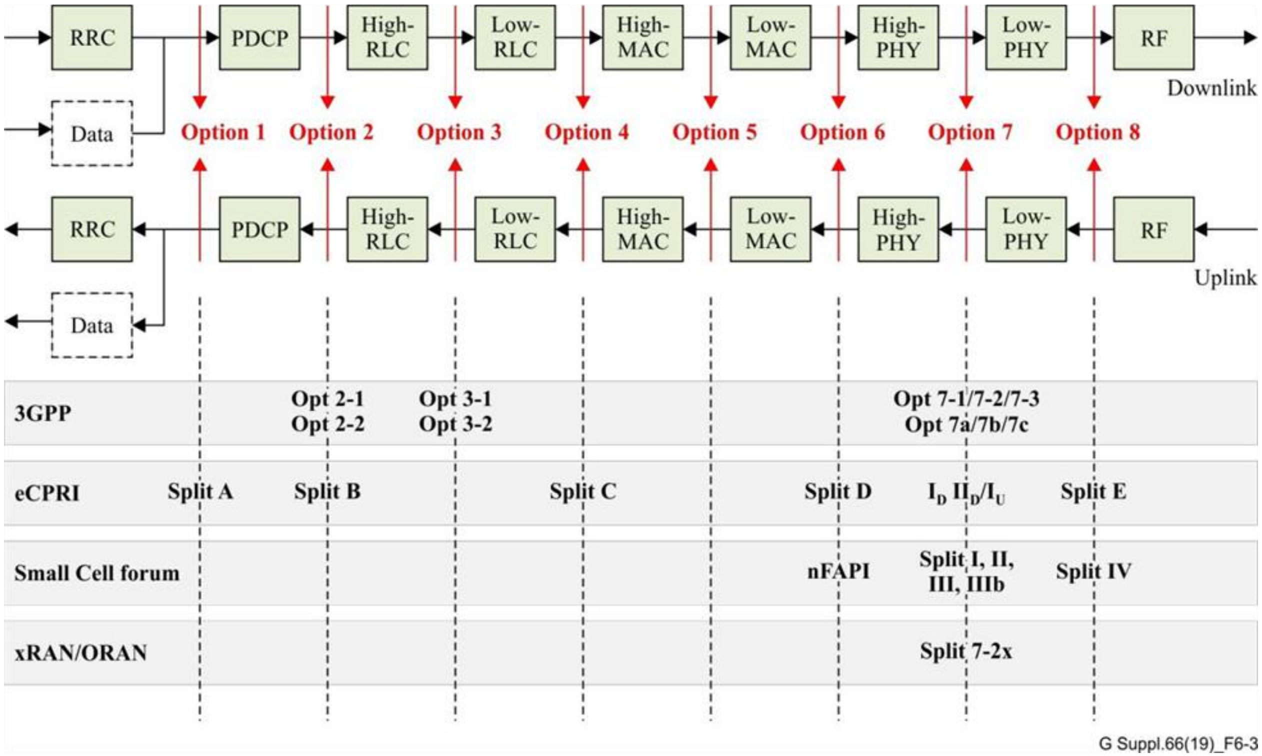
- Multiple RAN functional split options specified by 3GPP
  - Each split option has a number of implications and tradeoffs in terms of latency tolerances, fronthaul/backhaul capacity requirements, complexity, flexibility etc.




Source:3GPP

# Split Architectures

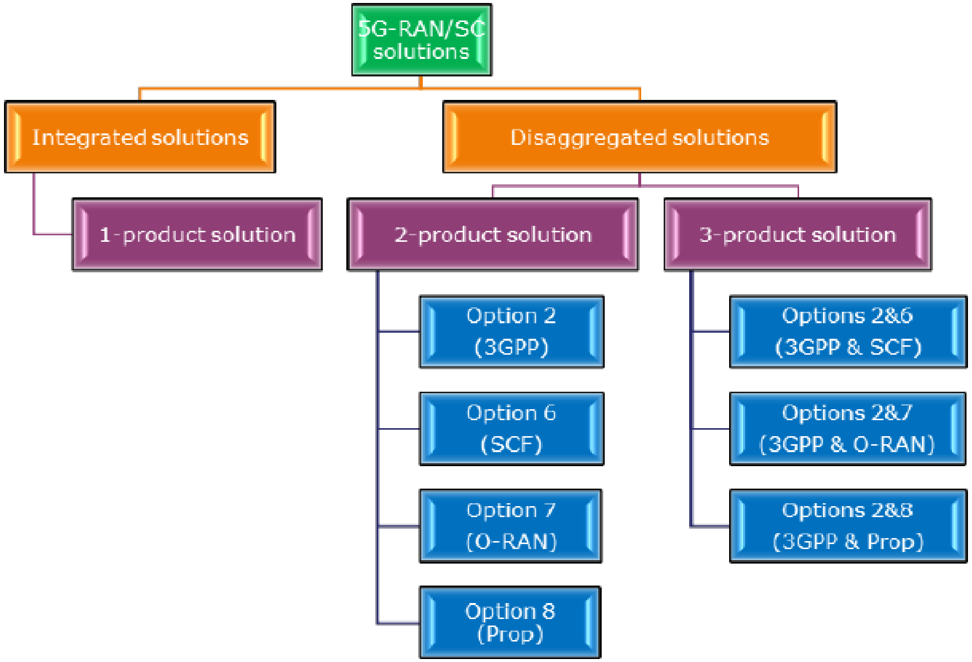
- 3GPP split options adopted by other SDOs or industry alliances
  - Specify disaggregated RAN products based on different splits
  - Specify open interfaces/APIs for intelligent RAN control, RAN service innovation, reduce vendor lock-in etc.

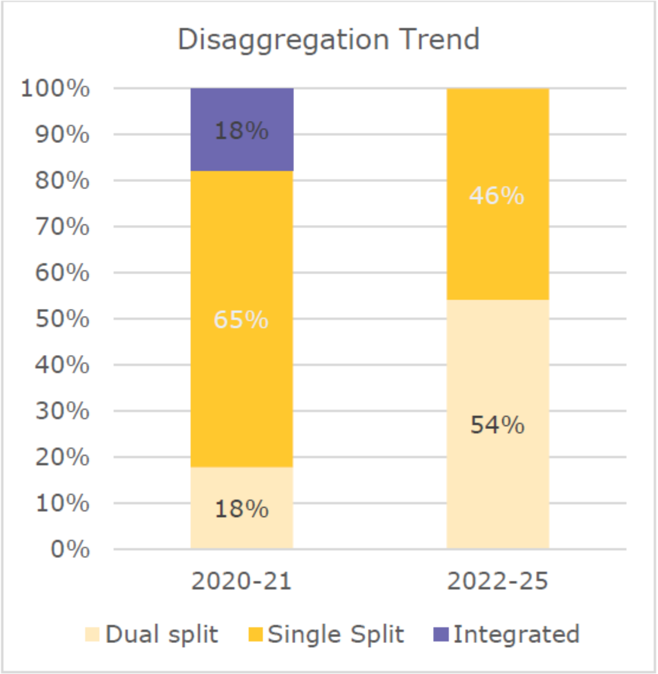



Source:ITU

# Split Architectures Trends

- RAN product classifications and projects from industry surveys by Small Cell Forum
  – *Integrated solutions*: Legacy solution with RU, DU and CU in one box
  – *Single split 2 product solutions*: e.g. RU/DU and CU as separate products
  – *Dual split 3 product solutions*: RU, DU and CU all as separate products




Source:Small Cell Forum

# Future Developments

# Some Example 5G NR Release 16 Work Items

- Operation in unlicensed bands (e.g. 60 GHz)
  - Complementing licensed bands
  - Similar to what is done in LTE-A Pro
- Enhancement of Ultra-Reliable (UR) Low Latency Communications (URLLC)
- Cellular IoT support and evolution
- Advanced V2X support
- 5G Location and Positioning Services
- Integrated Access and Backhauling (IAB)
- Satellite Access in 5G

# 5G NR Release 17 Work Items

- Includes several features approved to address different needs of vertical industries

## Release 17

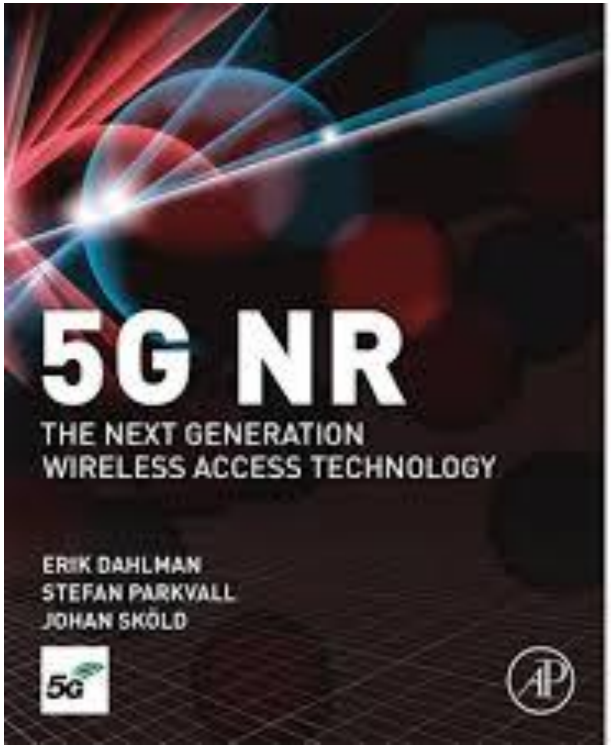
- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- Study - IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage enh.
- Study - NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G Multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR Sidelink relay
- RAN Slicing
- Enh. for small data
- SON / Minimization of drive tests (MDT) enh.
- NR Quality of Experience
- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network Automation for 5G - phase 2
- Edge Computing in 5GC
- Proximity based Services in 5GS
- Network Slicing Phase 2
- Enh. V2x Services
- Advanced Interactive Services
- Access Traffic Steering, Switch and Splitting support in the 5G system architecture
- Unmanned Aerial Systems
- 5GC LoCation Services
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

These are some of the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)

Start of work: January 2020

Full details of the content of Rel-17 are in the Work Plan: www.3gpp.org/specifications/work-plan

# Further Reading

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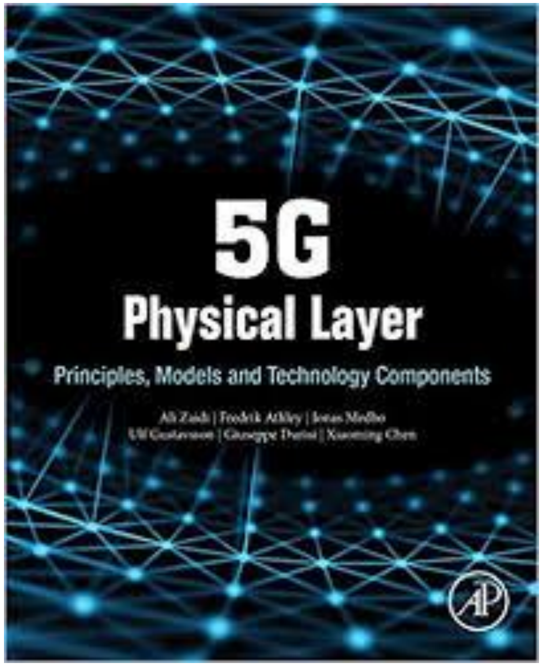


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**Thank You!**