

5G

3GPP specifications

- 3GPP (3rd Generation Partnership Project) specifications
 - Release 8+9: LTE
 - Release 10+11: LTE Advanced, HSPA+ (for UMTS)
 - Release 12+13: Some more LTE extensions, including NB-IoT and LTE-M for IoT and wireless sensor devices
 - Release 14: Faster LTE-M (~2.5MBit/s) and NB-IoT (~140kbit/s), lower power consumption for NB-IoT
 - Release 15 (2018/2019): 5G
 - Release 16 (2020/2021): Better support in 5G for satellite communication, vehicle to everything (V2X) and IoT,...

Release 15

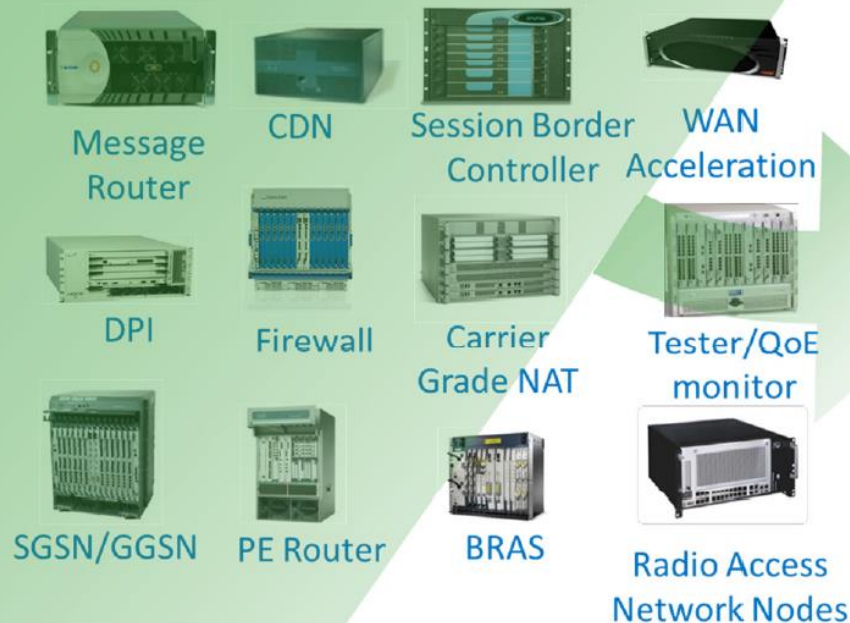
- 2018: “Non Standalone Access” (NSA)
 - Specification of a new radio access technology (5G NR)
 - Relies on the 4G Evolved Packet Core: Allows cellular providers to introduce 5G services in their 4G networks
 - UE with “dual connectivity” can connect to LTE base stations (eNB; evolved NodeB) and 5G-NR base stations (gNB; next generation NB)
 1. UE first connects to eNB and starts reporting measurements of 5G measurements
 2. eNB communicates with gNB to assign resources for 5G bearer
 3. Resource assignment is sent to UE (on LTE)
 4. UE connects to 4G and 5G networks

Release 15

- 2019: “Standalone Access”
 - Specification of a next-generation core network
- Relies on a “Service-Based Architecture”
 - Instead of traditional network components (gateways, MMEs,...), the core network contains “Network Functions”
 - Access and Mobility management Function
 - Session Management Function
 - User Plane Function
 - Network Repository Function
 - ...
 - NFs can be deployed in a fully distributed, redundant and scalable way on servers in a cloud, near the users (edge Computing),...

Network Virtualization

Classical Network Appliance Approach

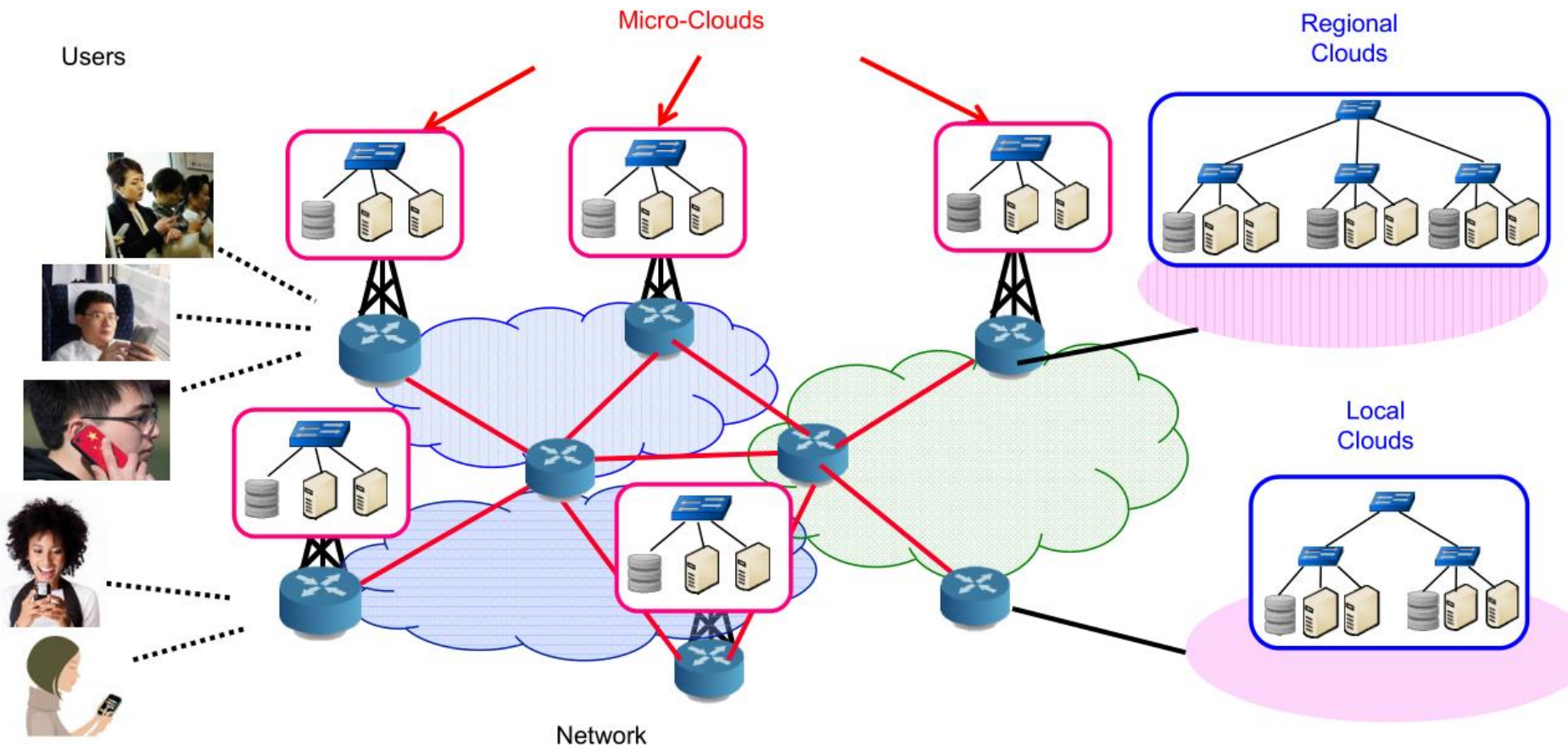


- Fragmented non-commodity hardware.
- Physical install per appliance per site.
- Hardware development large barrier to entry for new vendors, constraining innovation & competition.



Mobile Edge Computing

- Goal: Bring computation closer to the user



Source: Raj Jain

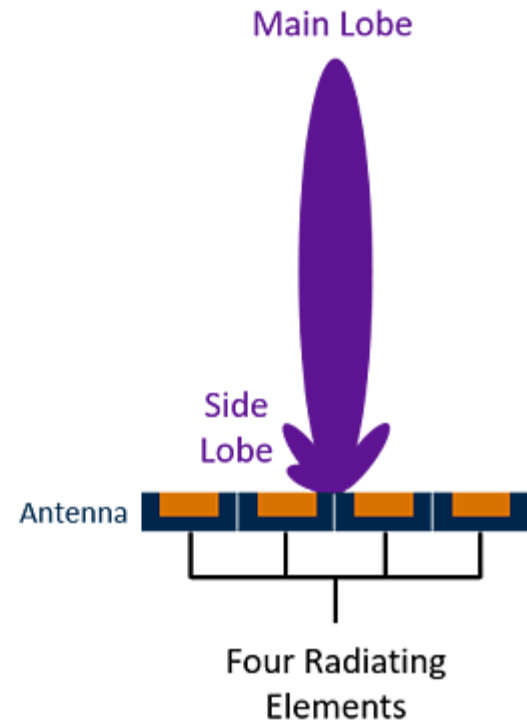
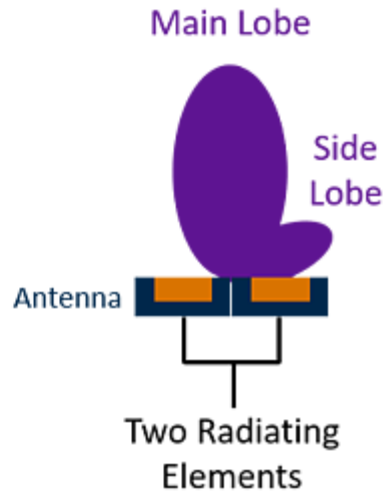
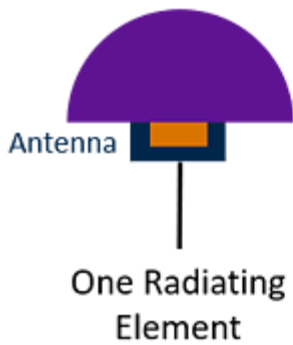
5G New Radio (1)

- Two frequency ranges
 - FR1: 450 MHz – 6000 MHz. Covers many frequency bands used previously by other services, for example GSM and LTE
 - mostly operated in FDD and TDD mode
 - Dynamic Spectrum Sharing: software update for 4G networks with a scheduler able to assign dynamically frequency bands to 4G or 5G connections
 - FR2: 24.25 GHz – 52.6 GHz (mm wave bands)
 - operated in TDD mode
- Remember:
 - TDD = Time Division Duplexing = Different timeslots for downlink and uplink
 - FDD = Frequency Division Duplexing = Different frequencies for downlink and uplink

5G New Radio (2)

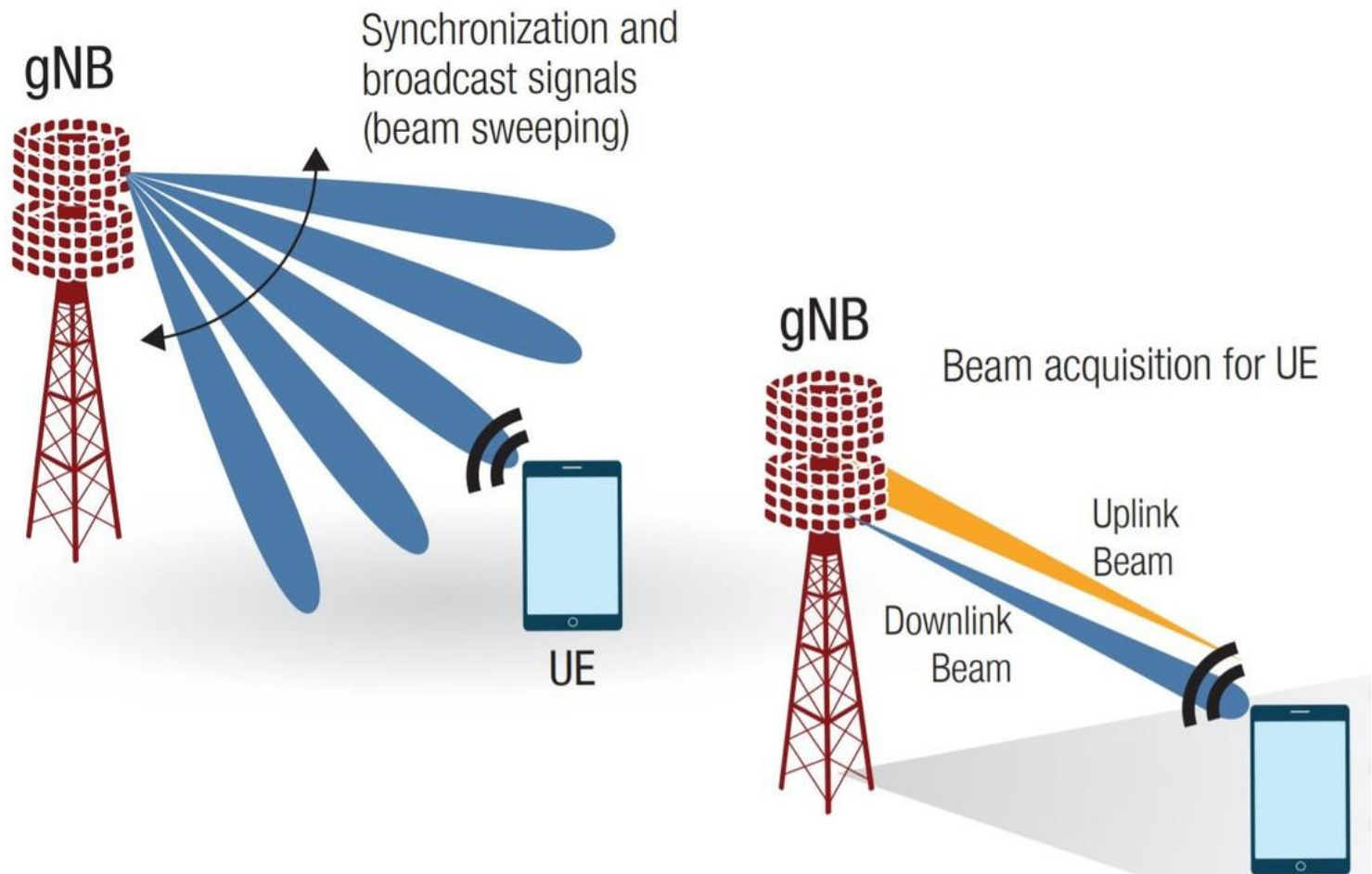
- Similar to LTE
 - Physical/Transport/Logical channels
 - OFDM
 - Different subcarrier sizes supported: 15/30/60 kHz for FR1 and 60/120/240 kHz for FR2
 - Timeslot duration 1ms for 15kHz (like LTE) to 0.0625ms for 240 kHz subcarriers
- Massive MIMO 64x4
 - Allows 3D beamforming
 - Multi-user MIMO: serve multiple users simultaneously by different beams
 - Is easier to implement with TDD than FDD. Also implemented for TDD LTE

Beam forming



Source: metaswitch.com

Beam management



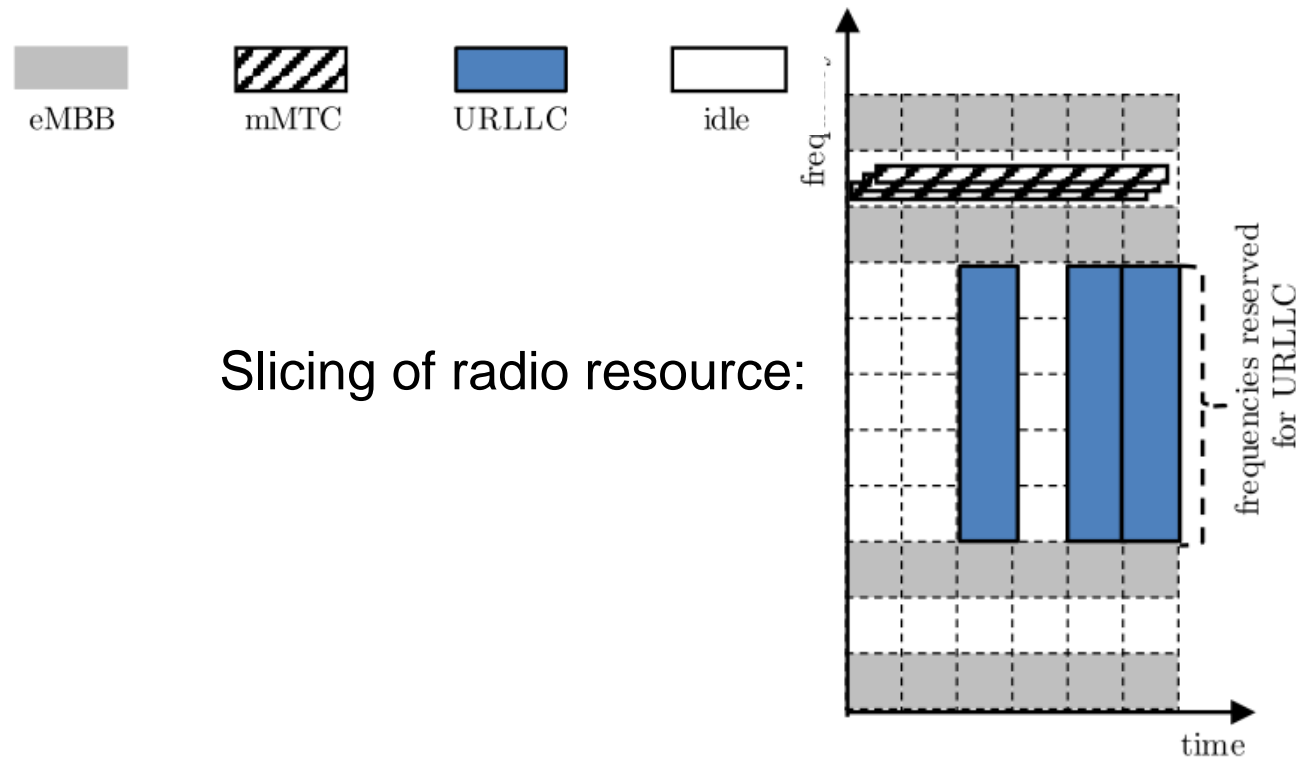
Source: Manoharan Ramalingam, Mavenir

Use cases

- Three use cases defined:
- eMBB (enhanced Mobile Broadband):
 - Like 4G, but faster
 - Peak data rate: Downlink: 20 Gb/s, Uplink: 10 Gb/s
 - Normal user: Downlink: 100 Mb/s, Uplink: 50 Mb/s
 - Latency 4ms for data, 20ms for control plane
- uRLLC (ultra Reliable and Low Latency Communication):
 - Latency 1ms and very low error rate
 - For critical applications, like autonomous driving
- mMTC (massive Machine Type Communication)
 - Up to 1 million devices per km²
 - RTT <10s for 20 bytes payload
 - Slow, possible collisions due to random access
 - For IoT

Network slicing

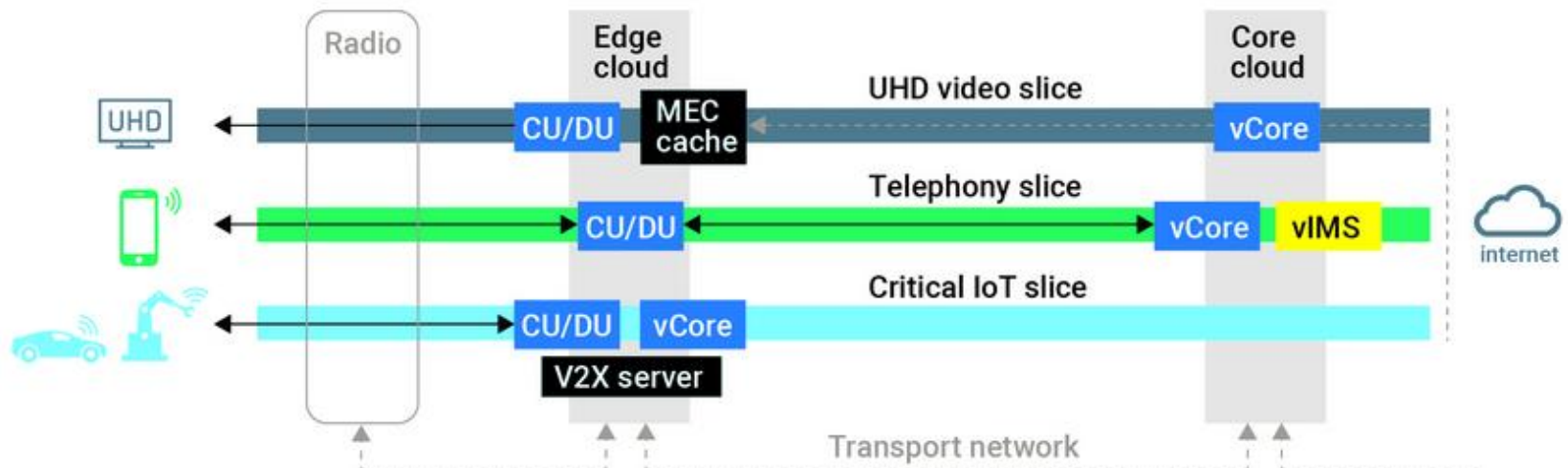
- The different 5G use cases run on the same infrastructure
- Network slicing is used to split the available resources such that bandwidth/latency/reliability guarantees can be given



From 5G Wireless Network Slicing for eMBB, URLLC, and mMTC: A Communication-Theoretic View. Popovski et al., 2018

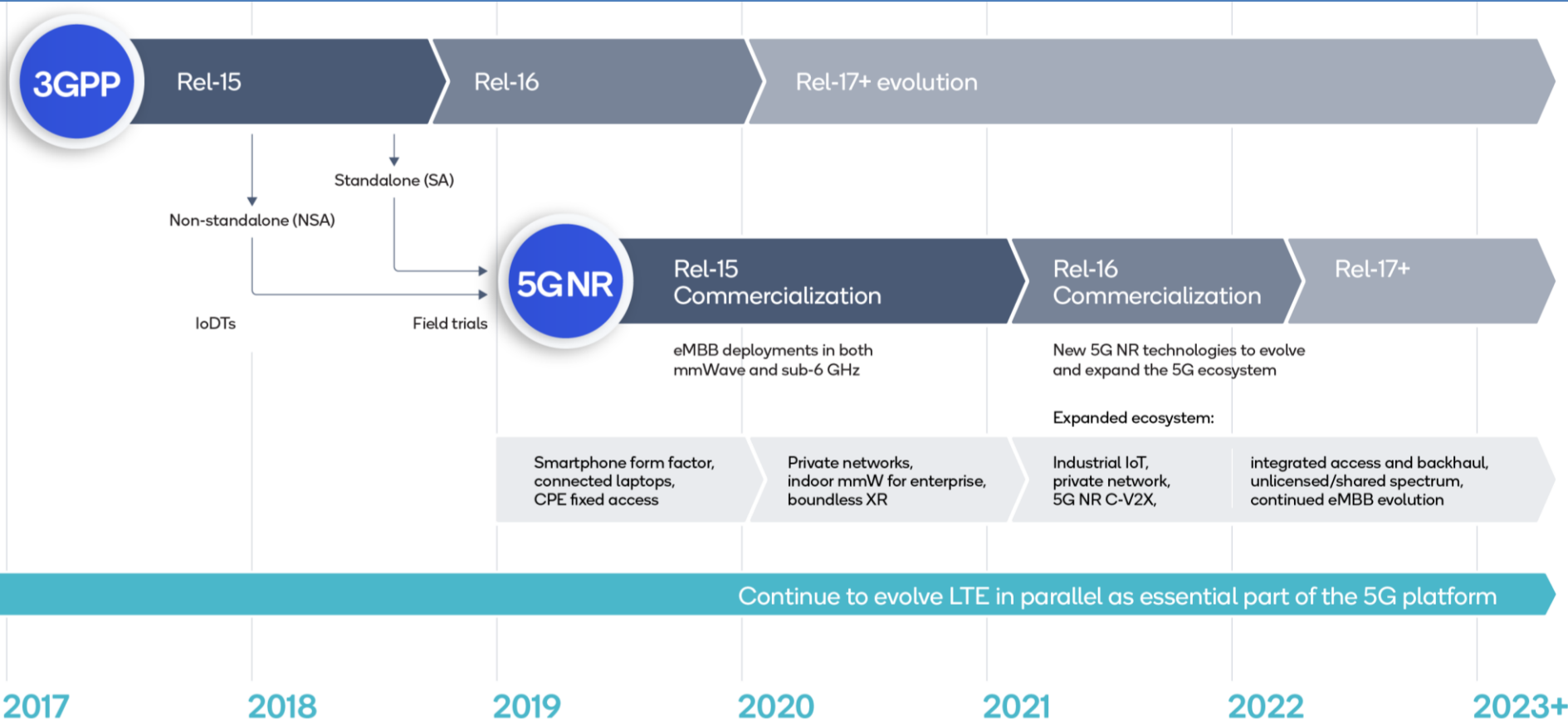
Network slicing (2)

- However, slicing is not only for the radio!
- To provide guarantees, all parts of the infrastructure, including the core network, the connection to the Internet, etc. have to be managed accordingly



<https://www.exfo.com/en/resources/blog/what-is-5g-network-slicing/>

5G Roadmap



Source: Qualcomm