3GPP 5G STANDARDIZATION

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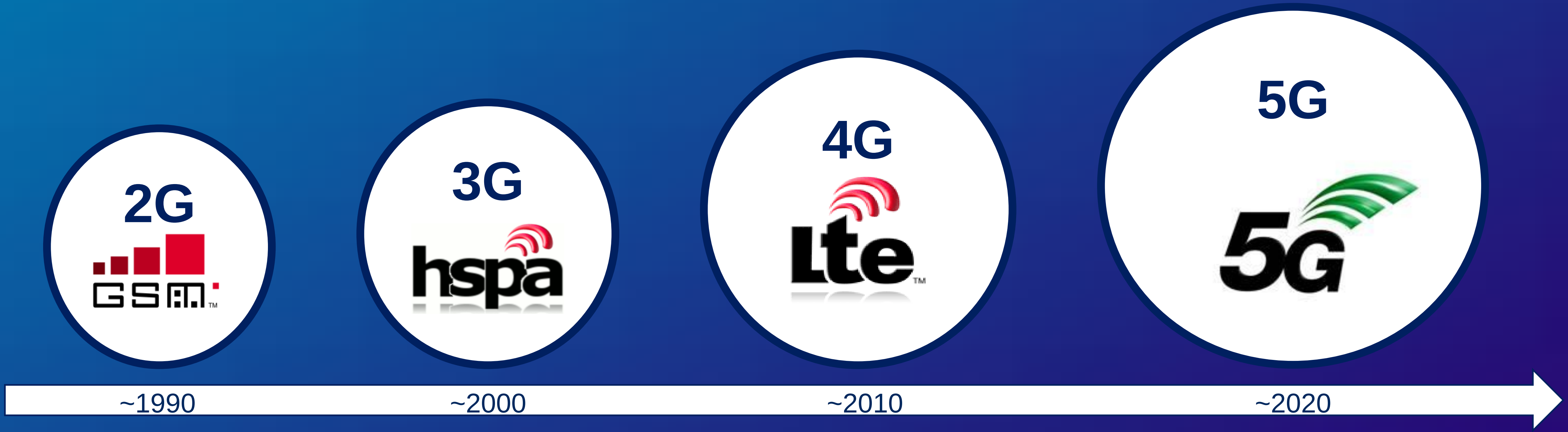
OUTLOOK

- Why?
  - 3GPP & ITU
  - New spectrum
  - New (and old) use cases
- When?
  - Non-standalone NR
  - Standalone NR
- What?
  - Support for low and high carrier frequencies
  - High performance
    - w.r.t. data rate, latency, capacity, and energy consumption
  - Flexible and future proof

WIRELESS ACCESS GENERATIONS



- 3rd Generation Partnership Project (3GPP) formed by regional standards organizations
  - USA, Europe, China, Korea, Japan, India
    - 630 Individual company members (Feb. 2019)
- 3GPP provides an environment to produce Reports and Specifications
  - GSM/GPRS, WCDMA/HS, LTE, …5G

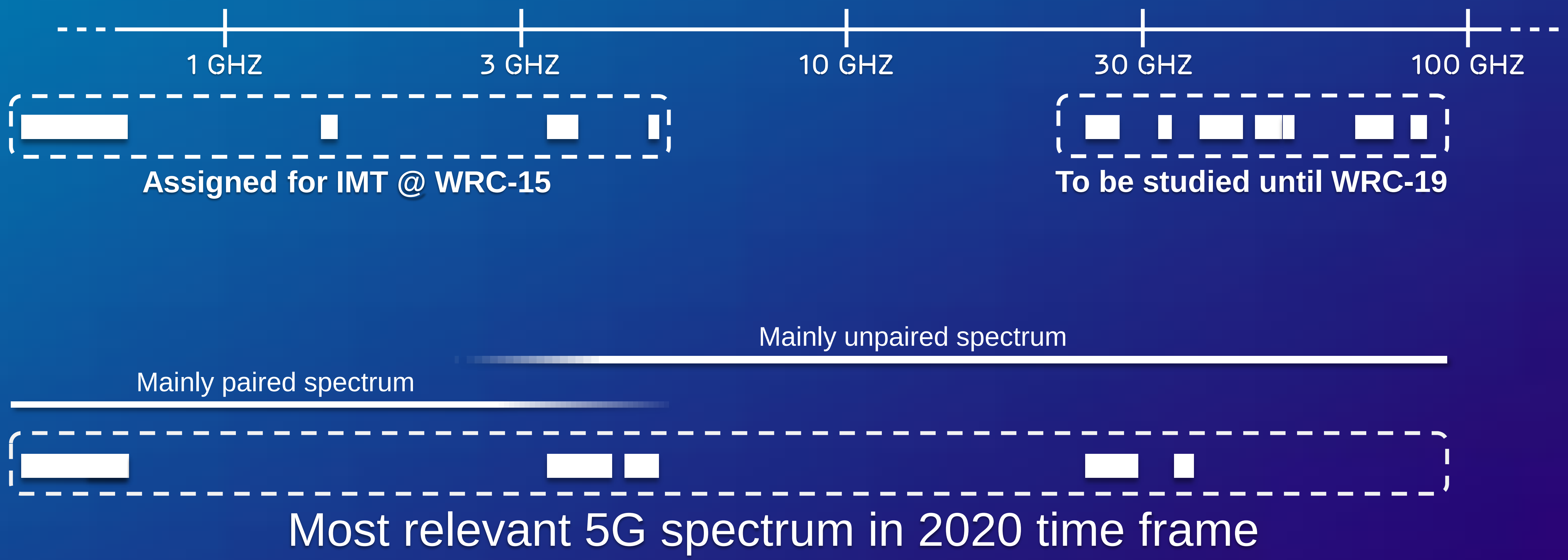
…basically 3GPP creates a <u>global eco system</u>!

INTERNATIONAL TELECOMMUNICATION UNION

- United Nations specialized agency for information and communication technologies
  - Sub-group ITU-R allocates global radio spectrum
    - World Radio Conferences (WRC) every ~4 years
  - Access to IMT (International Mobile Telecommunications) spectrum for ‘certified technologies’:
    - IMT-2000 → UMTS/HSPA, CDMA2000, EDGE
    - IMT-Advanced → LTE, WiMAX
    - IMT-2020 → NR, LTE*

* this talk focused on NR only

5G SPECTRUM RANGE



5G USE CASES

Massive Machine Type Communication

SMART METER

TRACKING

FLEET MANAGEMENT

Critical Machine Type Communication

INDUSTRIAL APPLICATIONS

TRAFFIC SAFETY & CONTROL

REMOTE MANUFACTURING

Enhanced Mobile Broadband

SMARTPHONES

VENUES

VR/AR

Fixed Wireless Access

4K/8K UHD

HOME BROADBAND

ENTERPRISE

?

ITU AND 3GPP REQUIREMENTS

Performance Measure	Requirement
Peak data rate	DL: 20 Gbps UL: 10 Gbps
Peak spectral efficiency	DL: 30 bps/Hz UL: 15 bps/Hz
Bandwidth	100MHz
Control plane latency	20ms (10ms encouraged)
User plane latency, 1-way	URLLC: 0.5ms, eMBB: 4ms
Infrequent small packets	10s / 20byte packet
Mobility interruption time	0 ms
Mobility	Up to 500 km/h
TRP spectral efficiency	3x IMT-A requirement
User spectral efficiency at 5% percentile	3x IMT-A requirement
Area traffic capacity	10Mbps/m^2 [ITU]
User experienced datarate	100/50 Mbps DL/UL [ITU]
MBB coverage (3GPP)	140/143 dB loss MaxCL

Performance Measure	Requirement
Connection density	1,000,000 devices/km^2
mMTC coverage (3GPP)	164dB coupling loss
Battery life (3GPP)	10-15 years
Reliability	1-10^{-5} in 1ms
NW energy efficiency	Inspection (Qualitative)
UE Energy efficiency	Inspection (Qualitative)
Inter-system mobility	Yes
Bandwidth scalability	Yes
Spectrum flexibility	Yes
Support of wide range of services	Yes

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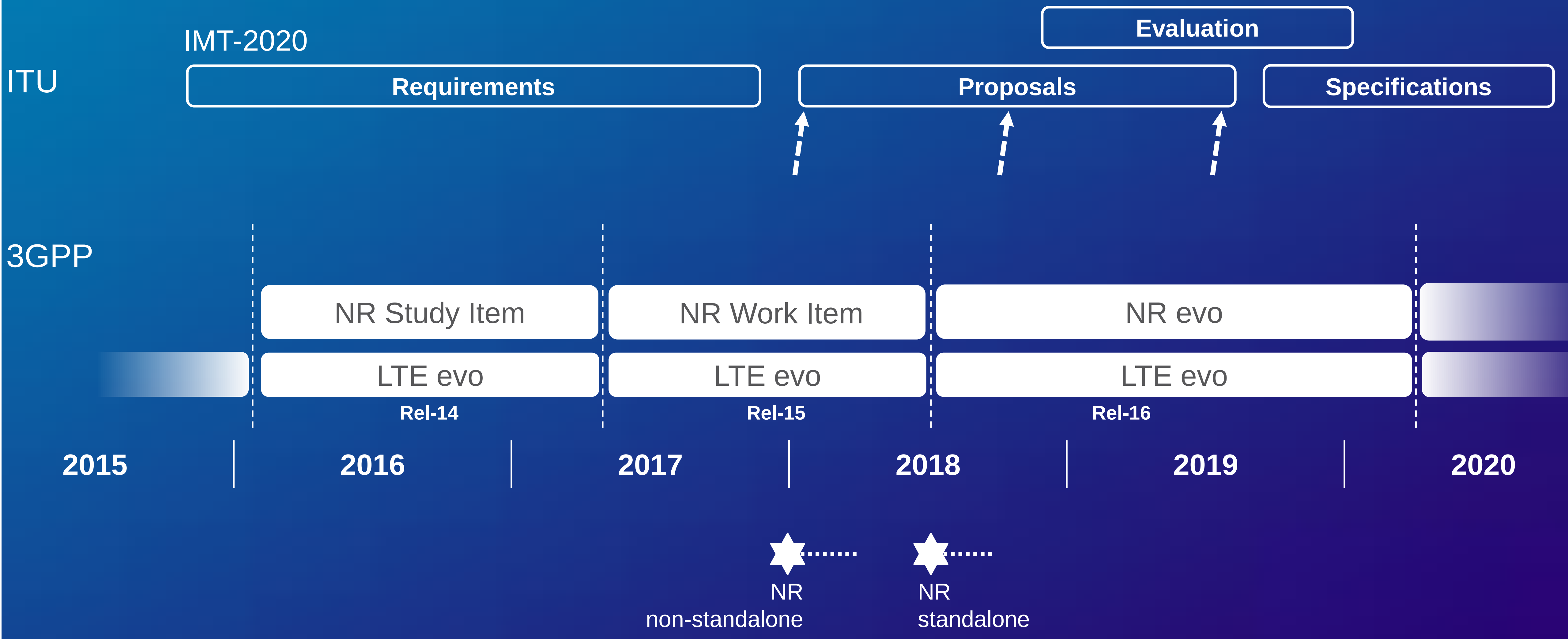
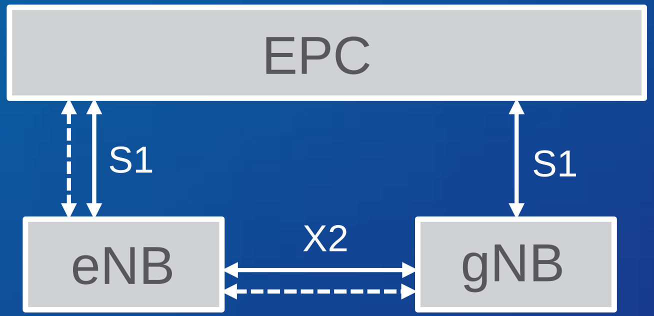
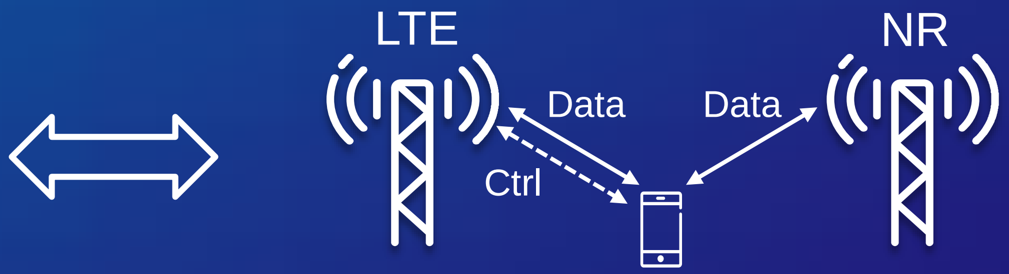
3GPP 5G TIMEPLAN



ACCELERATED 5G ARCHITECTURE

- Non-standalone NR with LTE master connected to Evolved Packet Core (EPC)
  - Based on LTE's Dual Connectivity framework designed for 'non-ideal' backhaul
- Standards approved in Dec. 2017

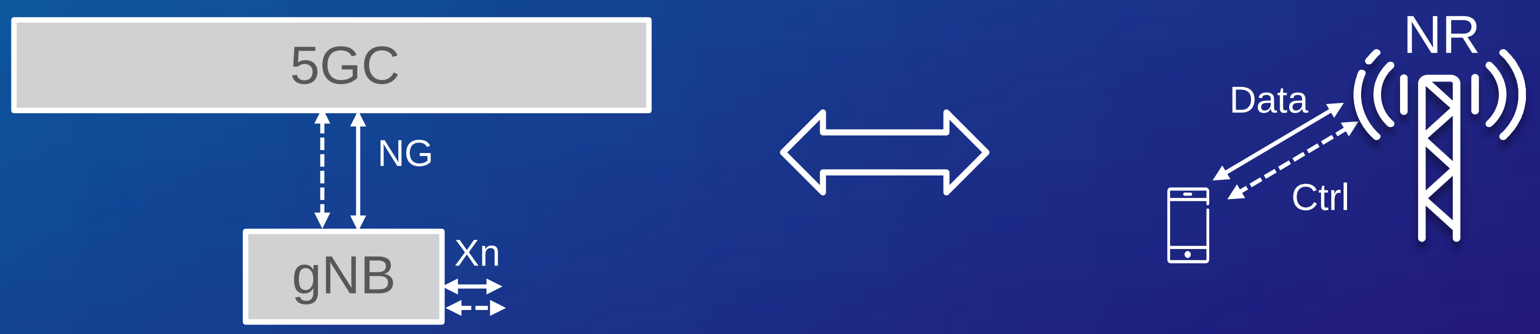




LTE/NR dual-connectivity

5G ARCHITECTURE OPTIONS

- Standalone NR connected to 5G Core Network (5GC)
  - Incl. NR-NR Carrier Aggregation and NR supplemental UL
- Standards approved in Jun. 2018



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FLEXIBLE NUMEROLOGY

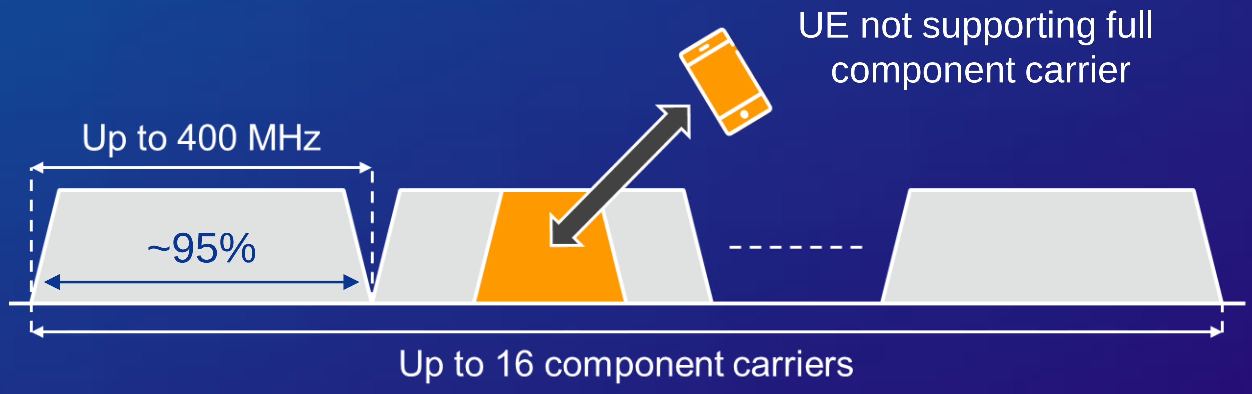
› OFDM with flexible sub-carrier spacing: $2^n \cdot 15$ kHz

Sub-carrier spacing	Resource block bandwidth	Slot length	Cyclic-prefix length
15 kHz	180 kHz	1 ms	4.69 µs
30 kHz	360 kHz	0.5 ms	2.34 µs
60 kHz	720 kHz	0.25 ms	1.17 µs / 4.16 µs
120 kHz	1.44 MHz	125 µs	0.59 µs
240 kHz	2.88 MHz	62.5 µs	0.29 µs

EFFICIENT / EFFECTIVE SPECTRUM USAGE

- Up to 400 MHz carrier bandwidth (LTE: 20MHz)
- ~95% spectrum utilization (LTE: 90%)
- Up to 16 carriers can be aggregated
- Devices may not support the full carrier bandwidth
- Possible co-channel sharing of UL and DL with LTE

Sub-carrier spacing	Maximum bandwidth
15 kHz	~50 MHz
30 kHz	~100 MHz
60 kHz	~200 MHz
120 kHz	~400 MHz
240 kHz	~400 MHz



SCHEDULING

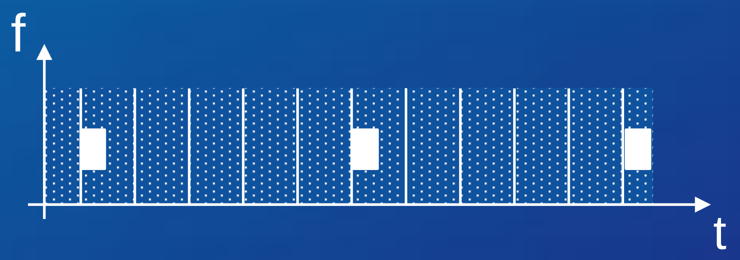
- Slot-based scheduling (like LTE)
- Multi-slot scheduling possible
- ‘Dynamic’ TDD
- Flexible (asynchronous) HARQ timing

- “Mini-slot” transmission
  - Transmission can start at any symbol and can have an almost arbitrary length
  - Enabling
    - low latency, feedback in same slot
    - Reasonable payload size
    - Quick access in unlicensed spectrum

LEAN DESIGN

› Minimize network transmissions not directly related to user-data delivery
   - Energy efficient networks
   - Low overhead
   - Interference minimization
   - Co-channel sharing, e.g. LTE and NR
   - Future-proof

LTE



- ”Always-on” reference signals
- Frequent ”broadcast” system information
- Full-bandwidth control channels
- Fixed timing relations
- ...

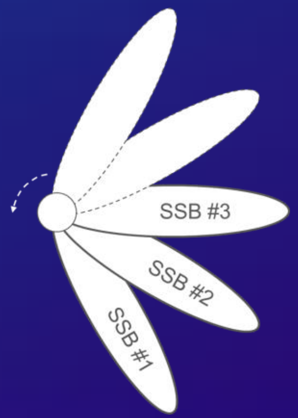
NR

- On-demand reference signals
- Sparser broadcast of minimum system information
- No mandatory full-BW transmissions
- Flexible timing
- ...

MIMO NATIVE

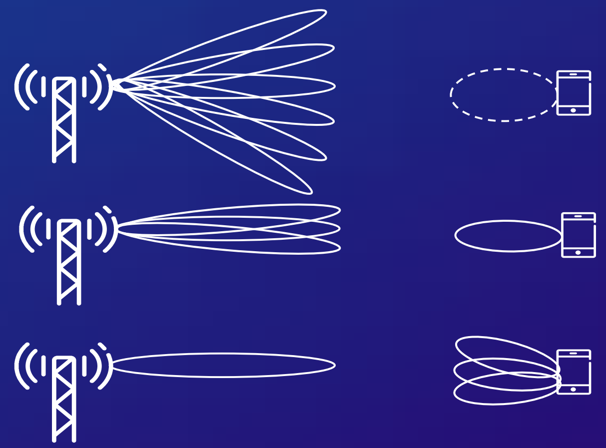
› Design principles:
  - Beamforming design for all transmissions (data, UE-specific- and common control)
  - For BS and UE beamforming
  - For digital- and analogue beamforming

› Common control signals
  - “SS blocks” containing synchronization signal and minimum system information
  - 20ms default (Idle UE) periodicity (LTE: 5ms)
  - Beam sweeping of SS blocks (up to 64)



MIMO NATIVE

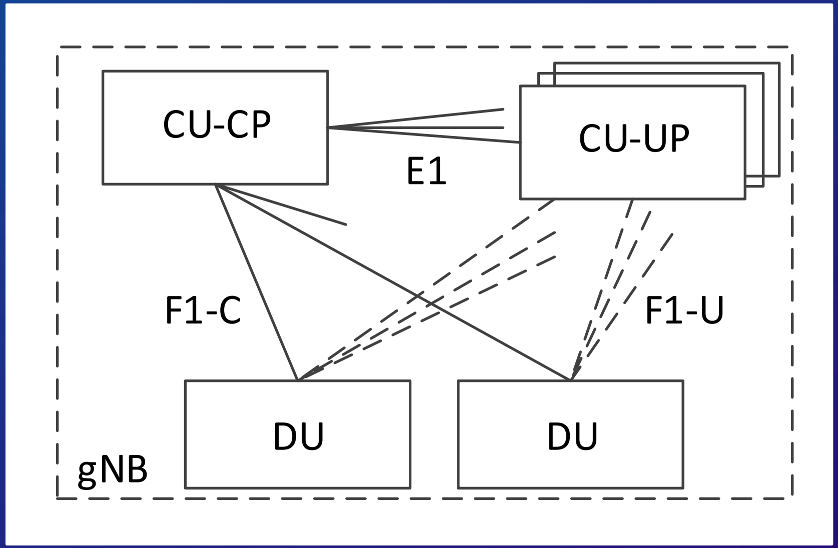
- DL Data Channel
  - LTE-like data channel using UE-specific reference signals
    - Up to 256QAM modulation
    - Up to 8 single-user MIMO layers (12 for multi-user MIMO)
    - Codebook-based and reciprocity based feedback
  - Simultaneous reception of two data channels to support cooperative base stations
  - ”self-contained transmissions” incl. (control), reference signals and data
    - Front loaded reference signals possible → fast decoding



- UL Data Channel
  - Up to 256QAM modulation
  - Up to 4 single-user MIMO layers (12 for multi-user MIMO)
  - Codebook-based and reciprocity based feedback
  - ”self-contained transmissions”

BASE STATION INTERNAL INTERFACES

- Central Unit (CU) – Distributed Unit (DU)
  - Realized by F1 interface
  - CU mainly contains PDCP protocol
  - DU mainly contains RLC/MAC/PHY
- Control Plane (CP) – User Plane (UP)
  - Realized by E1 interface
- Expectations:
  - Cost reduction through virtualization/cloudification
  - Flexible deployment
  - Separate scaling of nodes



5G NR

- Designed for new spectrum and use cases
  - eMBB, mMTC, cMTC, FWA …and future use
- Comes in 2 flavors
  - Non-standalone – standardized Dec. 2017
  - Standalone – standardized June 2018
- Superior air interface
  - Support for low and high carrier frequencies
  - High performance w.r.t data rate, capacity, latency, energy consumption
  - Flexible and future proof

FUTURE NR OUTLOOK

- NR on unlicensed spectrum
- Positioning
- Relaying
- Direct Vehicle-2-Vehicle communication
- NR for satellites
- …

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