5G NR mmWave Standards

Recent updates: NR bands & beam management

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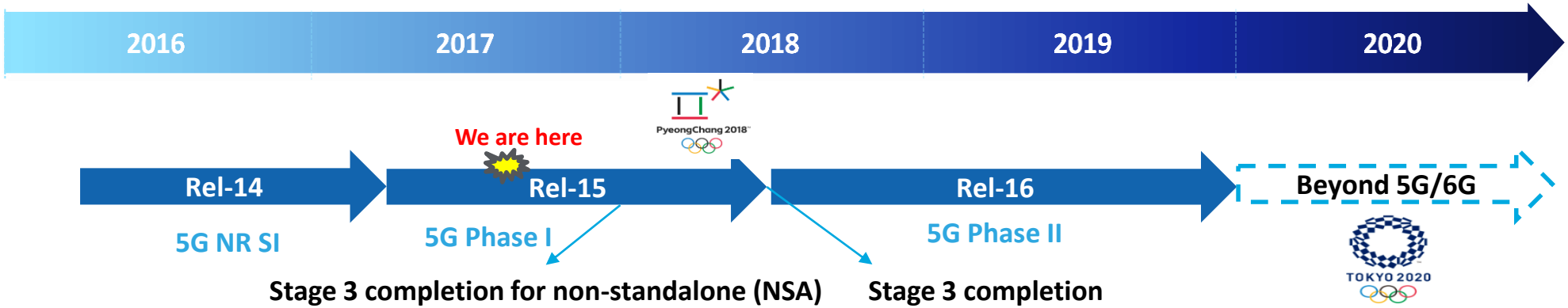
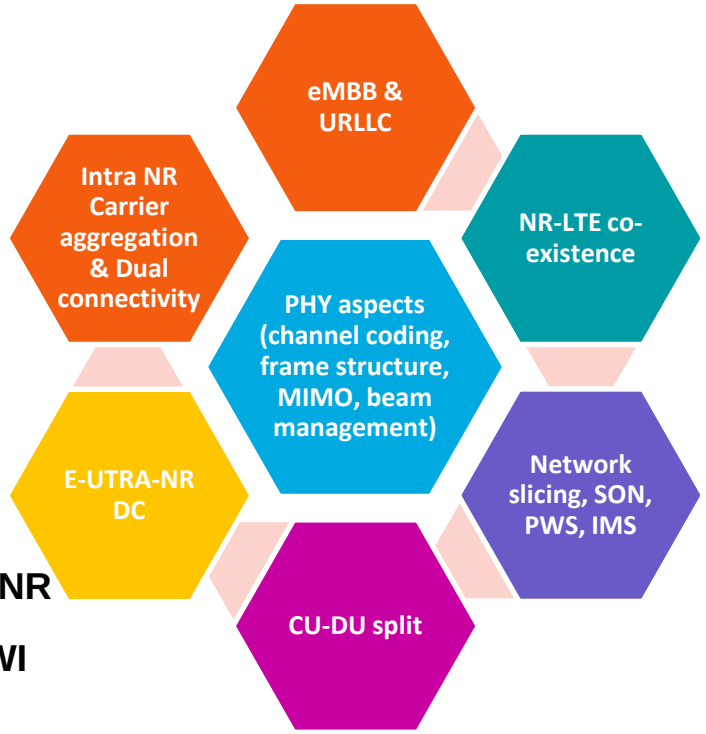
3GPP 5G (NR) standards

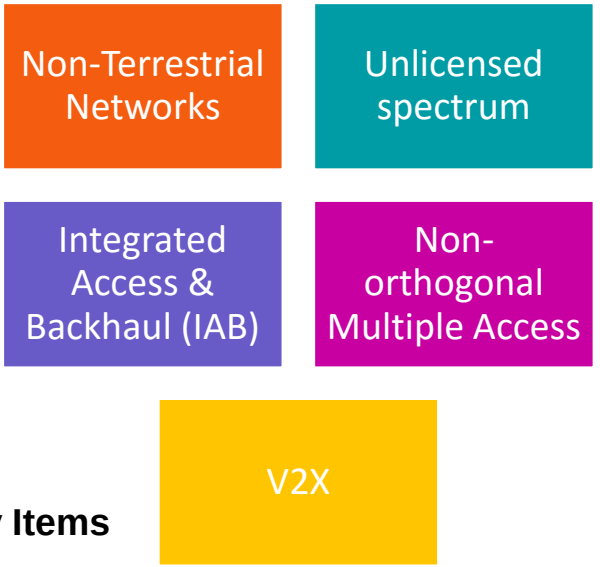


Stage 3 completion for non-standalone (NSA) (L1/L2 for both NSA and SA completed)

Stage 3 completion for standalone (SA)



Scope of NR Phase 1 WI



New NR Study Items (earliest start in Q4 17)

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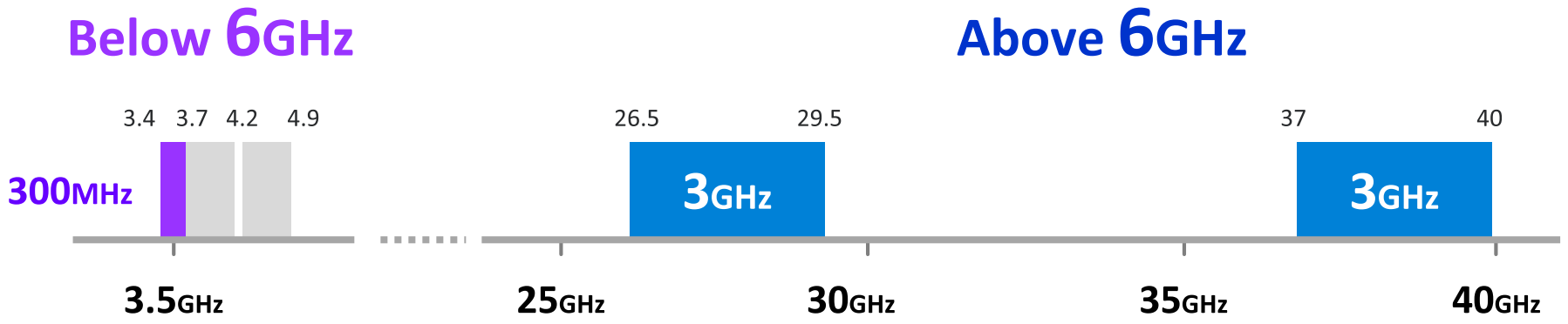
NR Candidate Frequencies

3.5GHz & 28GHz are Leading Candidates



Europe	3.4 - 3.8GHz
Korea	3.4 - 3.7GHz (300MHz)
Japan	3.6 - 4.2GHz, 4.4 - 4.9GHz
India	3.3 - 3.4GHz

USA	27.5 - 28.35GHz (850MHz)
Europe	24.25 - 27.5GHz
Korea	26.5 - 29.5GHz
Japan	27.5 - 29.5GHz

USA	37 - 40GHz (3GHz)

- Proposed bands below 3GHz in 3GPP
  : 600MHz (2x35MHz), 1.8GHz (2x75MHz), 2.5GHz (194MHz), … …

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3GPP NR Bands

- **Includes NR Bands for Standalone (SA) and LTE-NR band Combination for Non-standalone (NSA)**
- **Global operators show main interest in 3.5GHz band (<6GHz) and 28GHz band (>6GHz)**

Category		Frequency Range	Region/Operator
Above-6GHz		39GHz (37~40GHz)	US (AT&T/Verizon/T-Mobile)
		32GHz (31.8~33.4GHz)	Europe, UK (BT)
		28GHz (26.5~29.5GHz)	US (Verizon/AT&T/T-Mobile), Korea, Japan
		26GHz (24.25~27.5GHz)	Europe, UK (BT)
Below-6GHz	*New Spectrum*	4.5GHz (4.4~4.99GHz)	Japan, China
		3.5GHz (3.3~3.8GHz)	Korea, China, Europe
		3.5GHz (3.3~4.2GHz)	Japan, Europe
	LTE Bands	Band41 (2.5GHz)	US (Sprint)
		Band7 (2.6GHz)	UK (BT)
		Band66 (1.7/2.1GHz)	US (T-Mobile)
		Band71 (600MHz)	US (T-Mobile)
		Other LTE bands	

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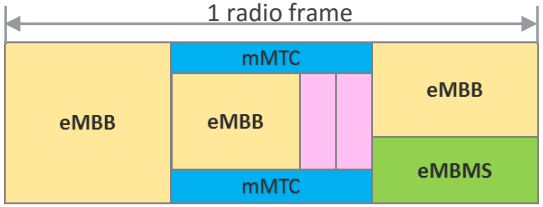
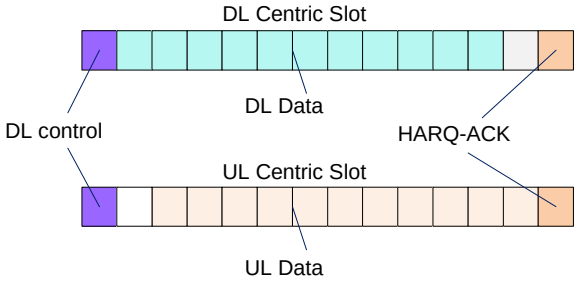
NR PHY Overview

Numerology & Waveform



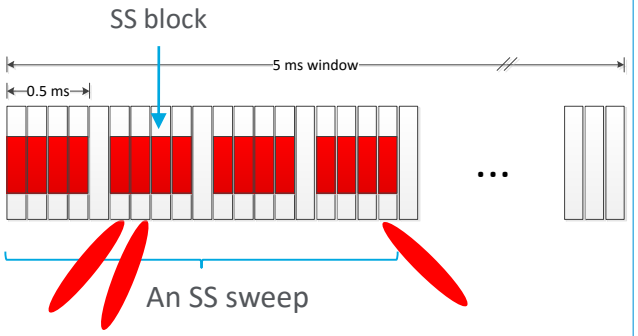
Efficient support of multiple services

Frame Structure



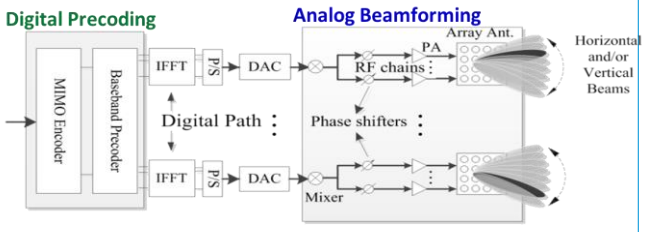
Self-contained slots

Initial Access & Mobility



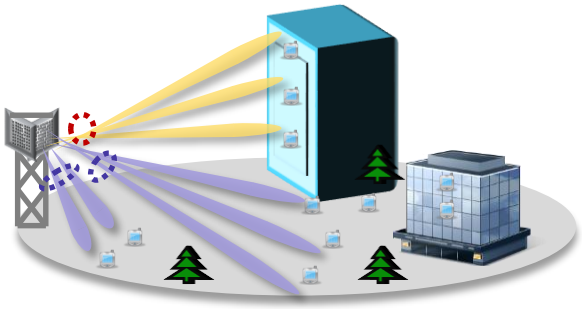
Beam sweeping for sync signals

mmWave Beam Management



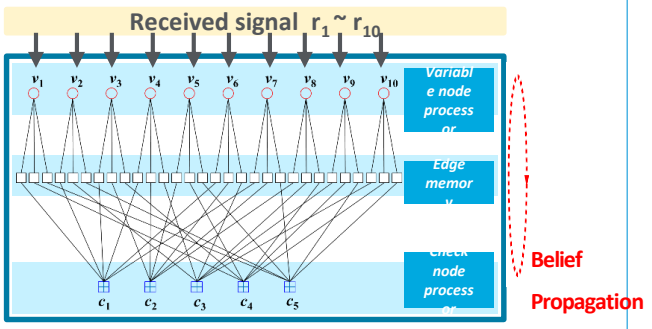
Hybrid beamforming

MIMO



High resolution & scalable CSI feedback

Channel Coding



Flexible LDPC & Polar Code

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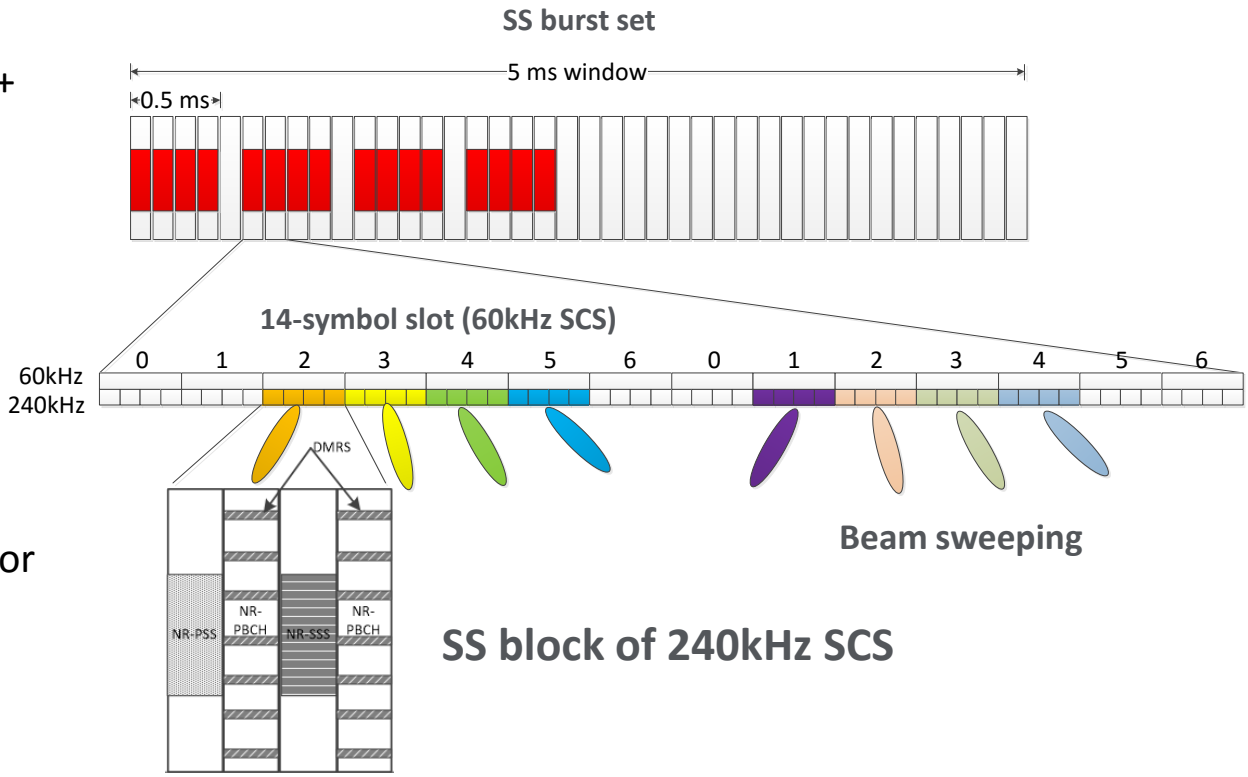
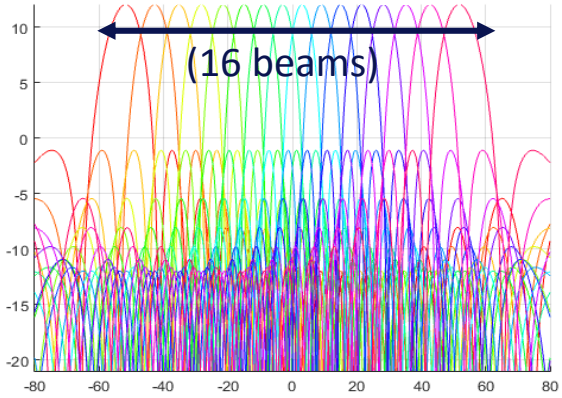
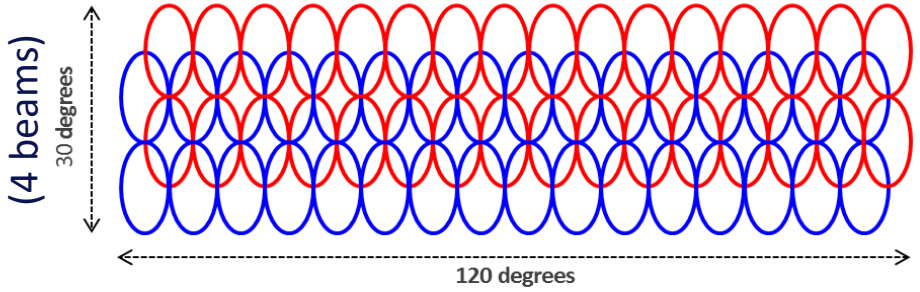
Scalable analog beams for synchronization

- **NR supports scalable analog beam sweeping of up to 64 beams per cell**
- Synchronization Signal (SS) block: NR-PSS + NR-PBCH + NR-SSS + NR-PBCH
- SS block subcarrier spacing (SCS): 120kHz or 240kHz; SCS for data: 60kHz or 120kHz.
  - Shorter SS block symbol reduces beam sweeping latency and overhead
- Max number of SS block in a SS burst set for mmWave bands is 64





120 degrees for azimuth direction



(16 beams)

Example 64 beams coverage

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NR beam management procedure

NR supports two-stage beam management procedure

1st stage beam alignment ("wide-beam")

- Based on measurement on SS block, or "wide-beam" CSI-RS
- Support robust communication (e.g. control channel)
- UE autonomous beam selection in idle mode
- Network controlled beam switching in RRC connected mode and dynamic (or semi-dynamic)

Note: Details of SS-block based beam management are under discussion in 3GPP

2nd stage beam alignment ("narrow-beam")

- Based on measurement on "narrow-beam" CSI-RS (UE-specific)
- Support high rate communication (e.g. data channel)
- Beam switching is network controlled & dynamic

SS block: Synchronization Signal block
CSI-RS: Channel State Information Reference Signal

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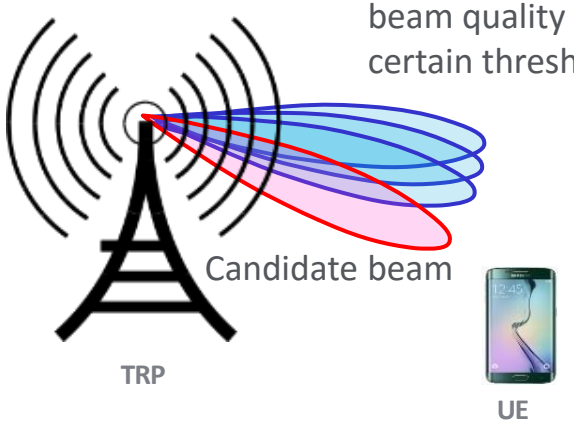
NR beam recovery procedure

- **NR supports UE-triggered procedure to recover from serving beam failure**

- **Trigger condition*:**
  1. When beam failure is detected AND
     - Beam failure : there is NO good control channel beams
  2. Candidate beam is identified
     - Candidate beam: Any CSI-RS beam and/or NR-SS beam

Beam failure: serving beam quality below a certain threshold



- **Beam failure recovery request transmission:**
  1. UE triggers random access procedure, or physical uplink control channel transmission
  2. Beam recovery request contains candidate beam info for connection re-establishment

- **UE monitors gNB response after sending beam failure recovery request**

*Note: Details of triggering condition are under discussion in 3GPP

RLF : Radio Link Failure
RACH : Random Access Channel

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Summary

NR bands

- **3.5GHz & 28GHz are leading candidates. Global operators show main interest in 3.5GHz band and 28GHz band**
- **mmWave bands**
  a. 26GHz band : 24.25~27.5GHz
  b. 28GHz band : 26.5~29.5GHz
  c. 32GHz band : 31.8~33.4GHz
  d. 39GHz band : 37~40GHz

NR Beam management

- **NR supports scalable analog beam sweeping of up to 64 beams per cell**
- **NR supports two-stage beam management procedure**
- **NR supports UE-triggered procedure to recover from serving beam failure**

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Thank you

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