5G NR mmWave Standards

Recent updates: NR bands & beam management

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3GPP 5G (NR) standards

2016	2017	2018	2019	2020

Rel-14 → **Rel-15** → **Rel-16** → **Beyond 5G/6G**

PyeongChang 2018

We are here

5G NR SI   5G Phase I   5G Phase II

TOKYO 2020

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

Stage 3 completion
for standalone (SA)

eMBB & URLLC

Intra NR Carrier aggregation & Dual connectivity

PHY aspects (channel coding, frame structure, MIMO, beam management)

NR-LTE co-existence

E-UTRA-NR DC

Network slicing, SON, PWS, IMS

CU-DU split

Scope of NR

Phase 1 WI

Non-Terrestrial Networks

Unlicensed spectrum

Integrated Access & Backhaul (IAB)

Non-orthogonal Multiple Access

V2X

New NR Study Items

(earliest start in Q4 17)

NR Candidate Frequencies

✓ **3.5GHz & 28GHz are Leading Candidates**

Below 6GHz   **Above 6GHz**

3.4 3.7 4.2 4.9   26.5   29.5   37   40

300MHz

3GHz   **3GHz**

3.5GHz   **25GHz**   **30GHz**   **35GHz**   **40GHz**

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), … …

SAMSUNG
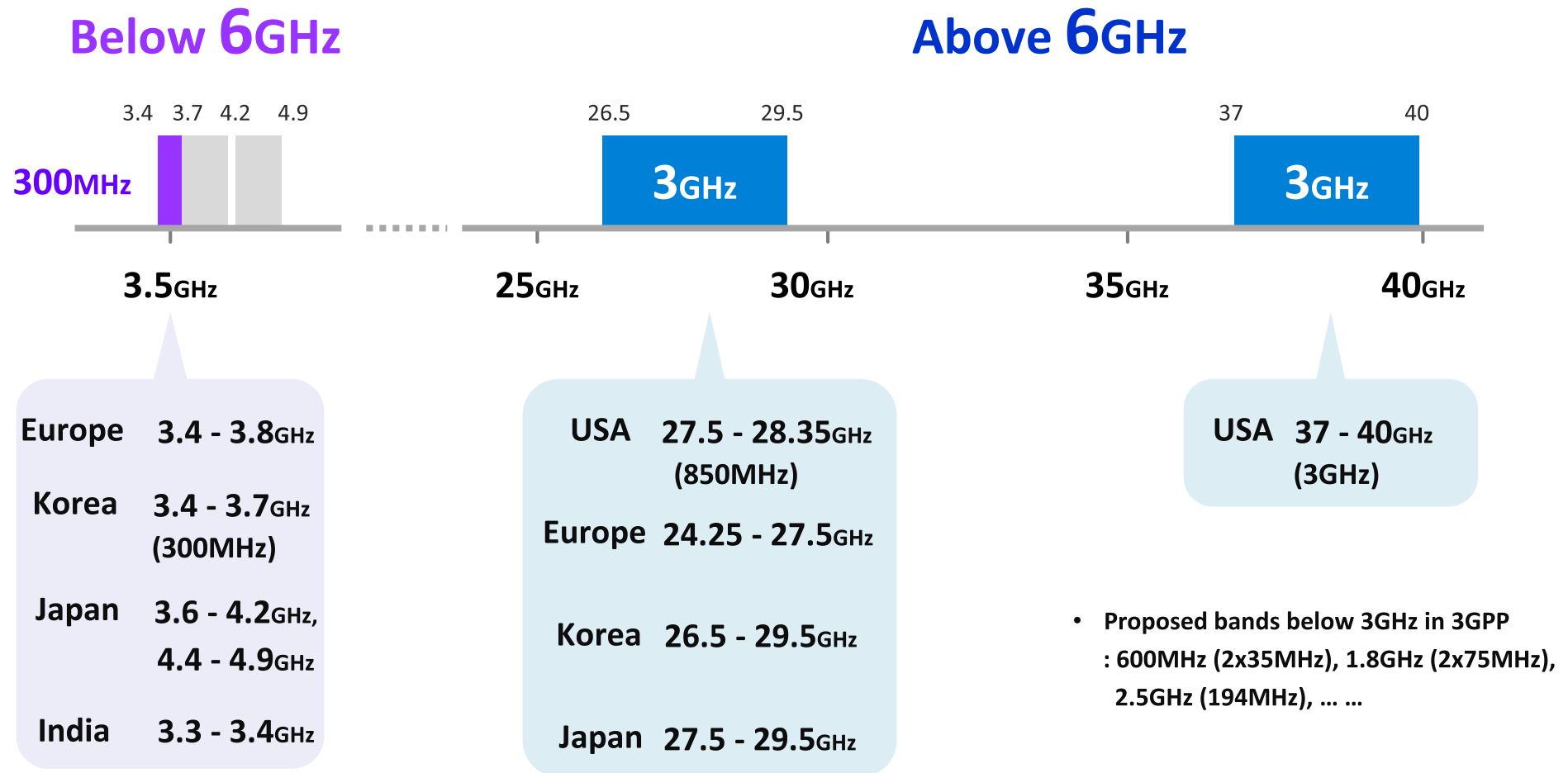
3GPP NR Bands

- ✓ **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	

NR PHY Overview

Numerology & Waveform

1 radio frame

**Efficient support
of multiple services**

Frame Structure

DL Centric Slot

DL Data

DL control

HARQ-ACK

UL Centric Slot

UL Data

Self-contained slots

Initial Access & Mobility

SS block

5 ms window

0.5 ms

An SS sweep

Beam sweeping for sync signals

mmWave Beam Management

Digital Precoding

Analog Beamforming

Hybrid beamforming

MIMO

**High resolution &
scalable CSI feedback**

Channel Coding

Received signal $r_1 \sim r_{10}$

Belief
Propagation

Flexible LDPC & Polar Code

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

SS burst set

5 ms window

0.5 ms

14-symbol slot (60kHz SCS)

60kHz
240kHz

DMRS

NR-PSS | NR-PBCH | NR-SSS | NR-PBCH

SS block of 240kHz SCS

Beam sweeping

(16 beams)

(4 beams) 30 degrees

120 degrees

(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

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

Candidate beam

TRP

UE
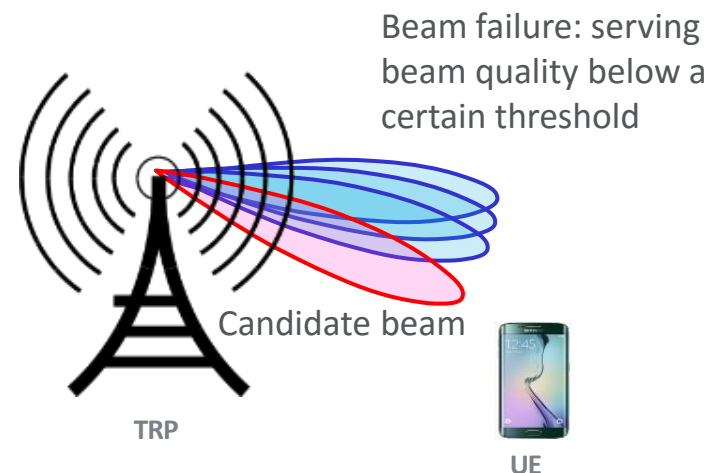
✓ **Beam failure recovery request transmission:**

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

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**

Thank you