SAMSUNG Research

5G Tech Sessions

September 27, 2018

Presented by:

ITU-APT Foundation of India & SAMSUNG

5G Tech Sessions - Agenda & Speakers

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- [16:00 – 16:10] 5G Introduction

Suresh Chitturi
3GPP SA6 Chairman
Director, Standards

- [16:10 – 17:00] 5G Radio (NR)

Anshuman Nigam
3GPP RAN1
5G R&D Lead

Mangesh Ingale
3GPP RAN2
TSDSI SG2 VC

Diwakar Sharma
Regional Standards
5G Spectrum

- [17:00 – 17:40] Next-Generation/5G Core

Lalith Kumar
3GPP CT1
5G Core & NAS

- [17:40 – 18:20] 5G Security

Naren Tangudu
3GPP SA3
5G Security

- [18:20 – 19:00] Emerging 5G Verticals

Basavaraj Pattan
3GPP SA6
5G Services/APIs

Disclaimer

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ITU-APT Foundation of India - 5G TECH SESSIONS

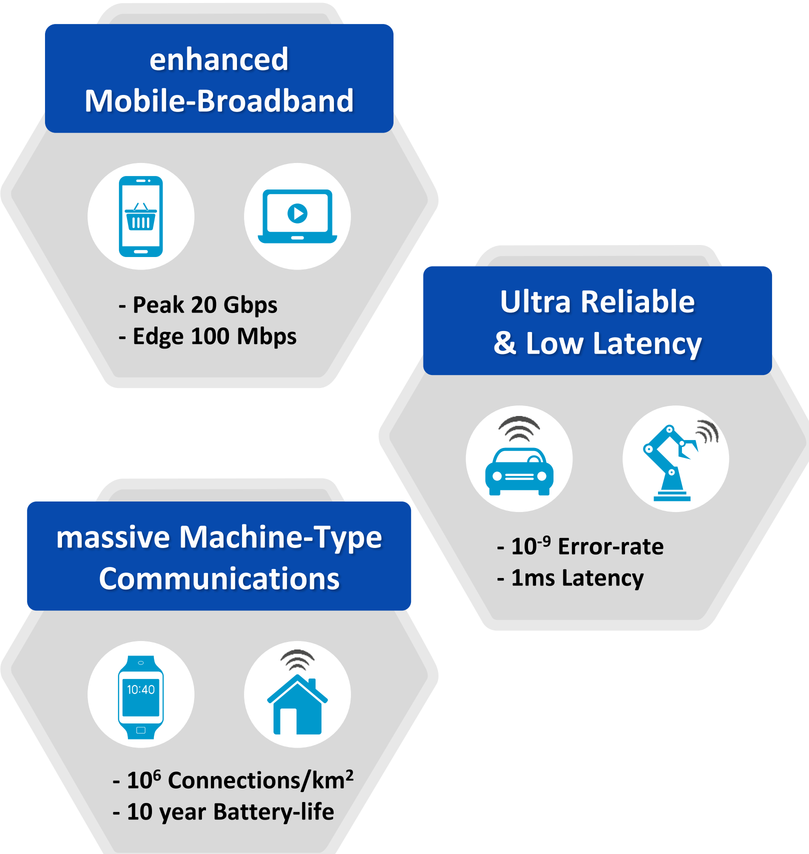
5G Introduction

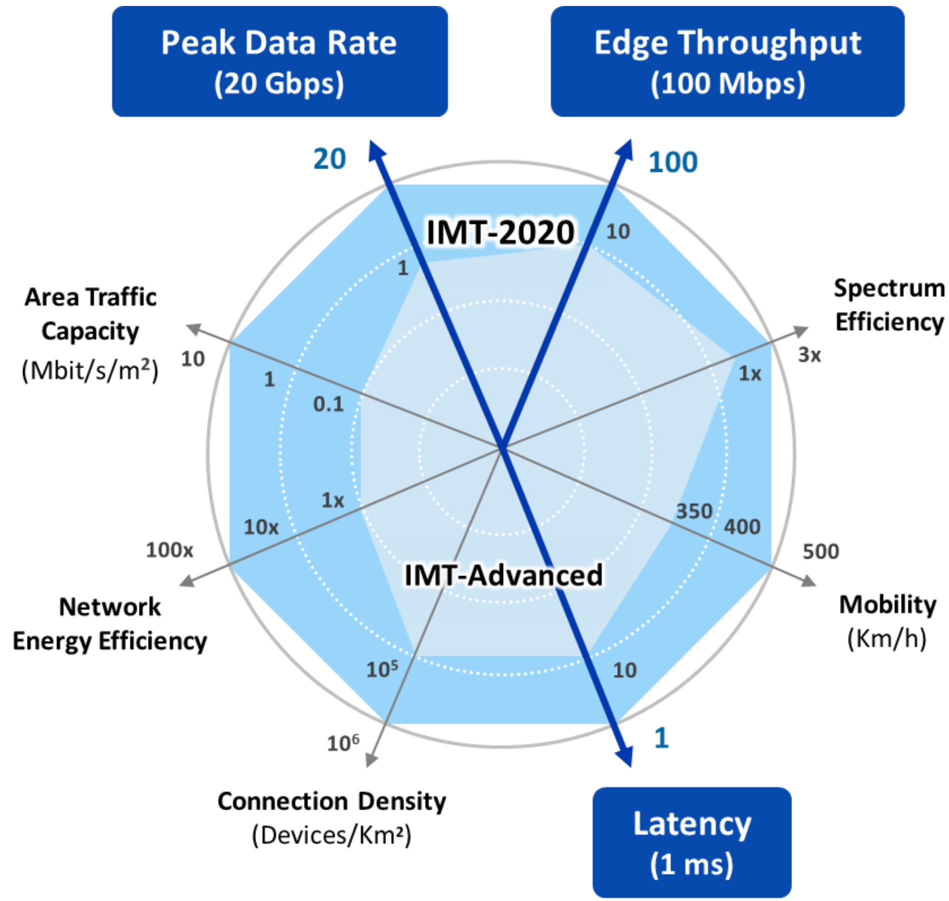
September 27, 2018

Samsung R&D, Bengaluru

5G Vision

Enable New Services through Convergence of Radio/Network Technologies





※ M.2083 : IMT Vision - "Framework and overall objectives of the future development of IMT for 2020 and beyond"
http://www.itu.int/rec/R-REC-M.2083

5G Standard Timeline - 3GPP

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First 5G NR(New Radio) Standard Available in 2018

2016 | 2017 | 2018 | 2019 | 2020

PyeongChang 2018

TOKYO 2020

5G Study | 5G Phase I | 5G Phase II

Mar. 2016 | Mar. 2017 | Dec 2017 | Jun. 2018 | Dec. 2018 | Dec. 2019

Rel-14 | Rel-15 | Rel-16

Beginning of 5G Standardization

5G Study Item
(3GPP, 2016.03)

NSA EN-DC
(Dec. 2017)
Early Drop

SA

NSA MR-DC
(Dec. 2018)
Late Drop

IMT-2020
Submission

5G Ph-1 Completed
(3GPP, 2018.06)

3GPP Structure & Leadership

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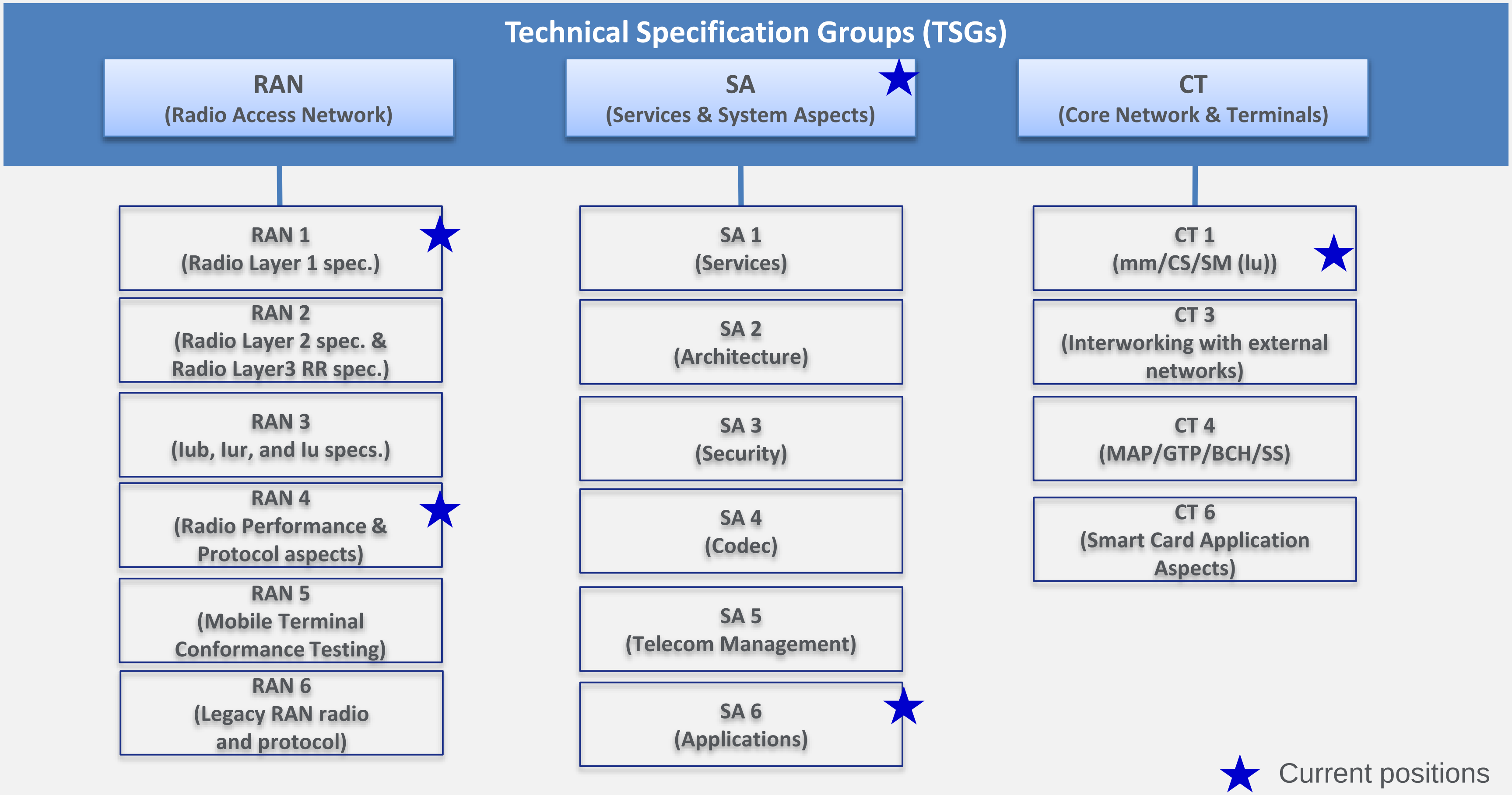
Samsung has 5 leadership positions in 3GPP



※ SA Chair (Erik Guttman), SA6 Chair (Suresh Chitturi), RAN4 Chair (Xutao Zhou), RAN1 Vice Chair (Younsun Kim), CT1 Vice Chair (Ricky Kaura)

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IAFI - 5G TECH SESSIONS

5G Radio

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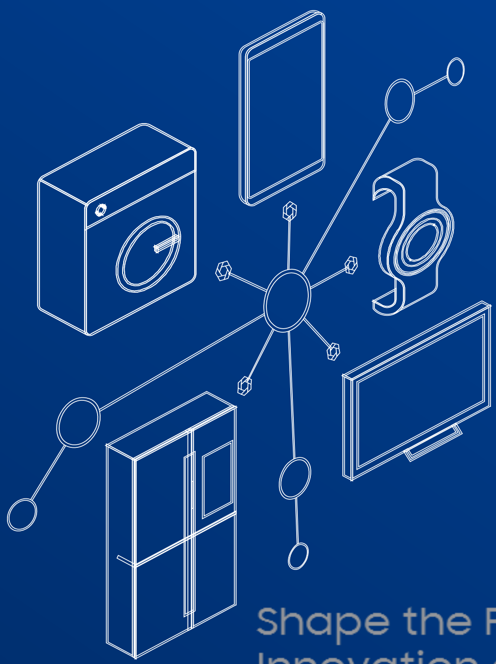

Shape the Future with
Innovation and Intelligence

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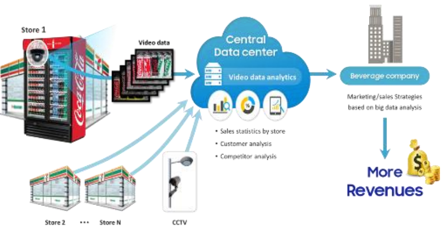
Ⅰ. 5G Physical Layer

Key Attributes of 5G NR Standards

Flexibility

Time, Dynamic

Frame Structure, Control Channels
On Demand Reference Signals, …



Diversity

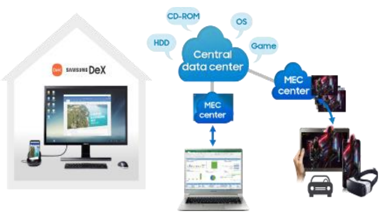
Use case Specific

E2E Network Slicing,
Designed for URLLC & mMTC, …

Scalability

Deployment

Virtualization, Migration Option (NSA SA),
Edge Computing, Future Hooks, …



Flexible Numerology – Enabling Plethora of Services

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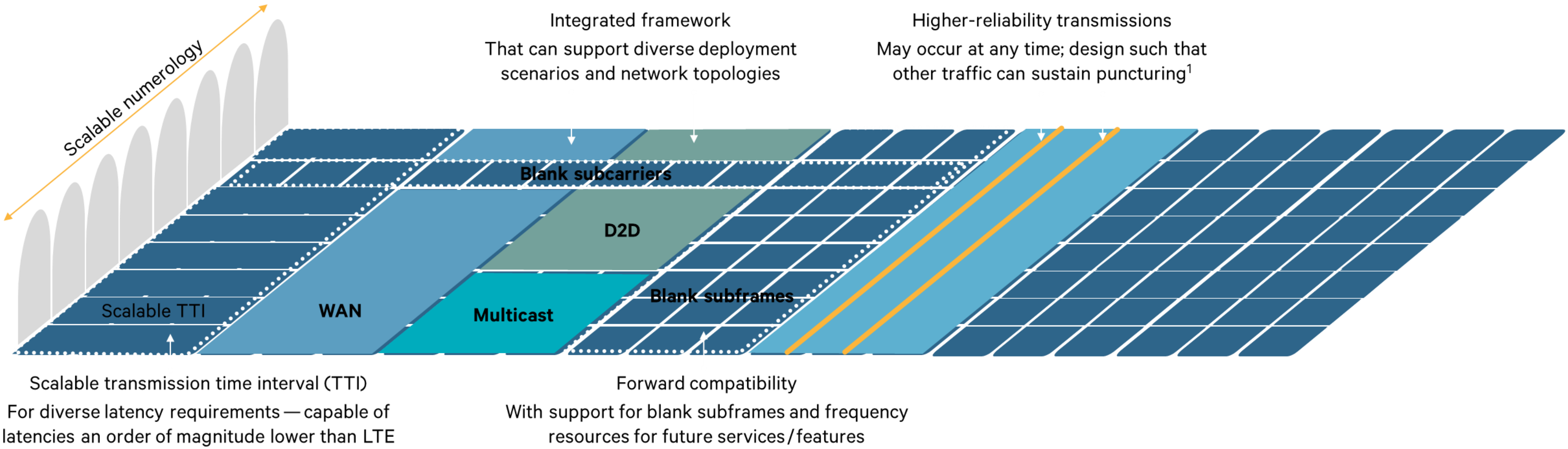
Designed to multiplex envisioned & unforeseen 5G services on the same frequency

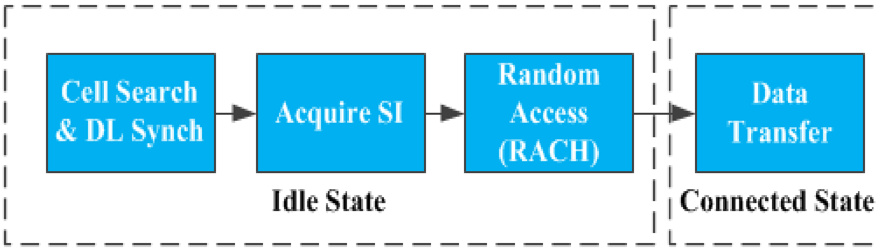


SCS	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	40 MHz	50 MHz	60 MHz	80 MHz	100 MHz
15 kHz	25	52	79	106	133	216	270	N.A	N.A	N.A
30 kHz	11	24	38	51	65	106	133	162	217	273
60 kHz	N.A	11	18	24	31	51	65	79	107	135

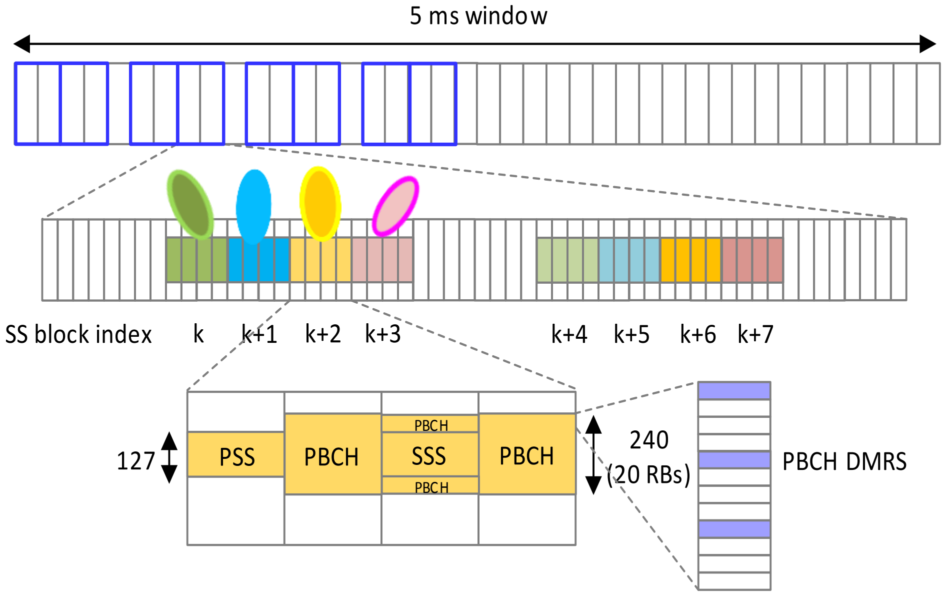
SCS	50 MHz	100 MHz	200 MHz	400 MHz
60 kHz	66	132	264	N.A
120 kHz	32	66	132	264

Initial Access

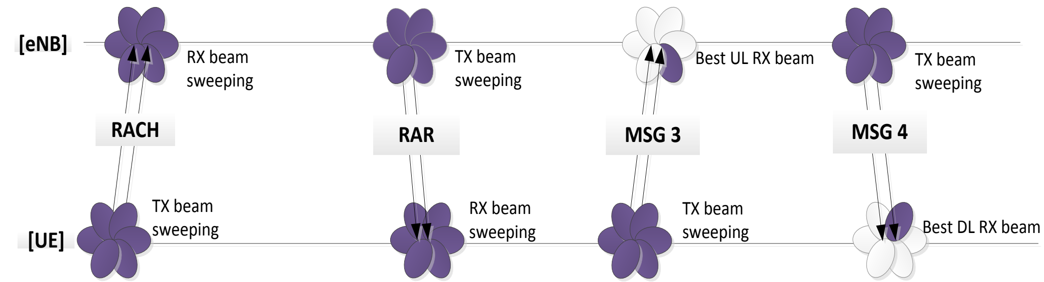
Initial Access: Move to Connected



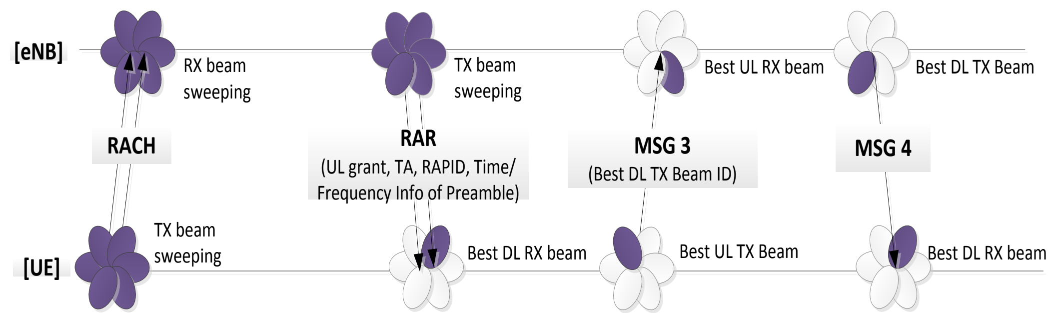
Synchronization: Sweeping of Beams



Random Access: Sweeping of Beams



Beamformed Random Access without enhancement



Beamformed Random Access with enhancement

Control Channels: PDCCH & PUCCH

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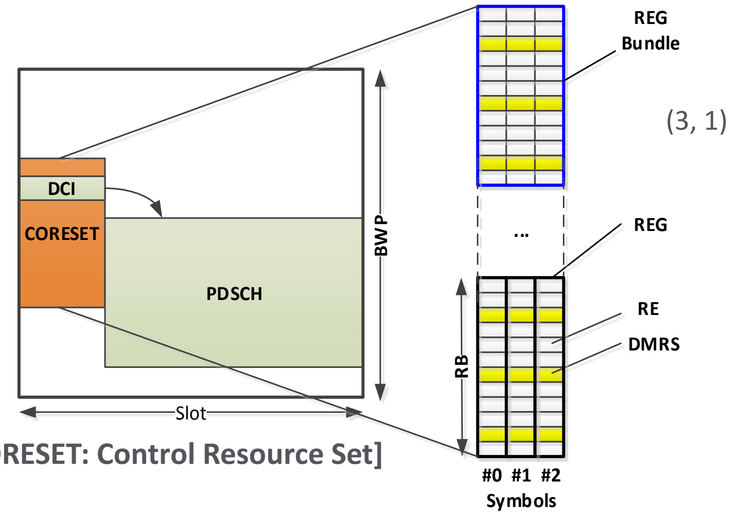
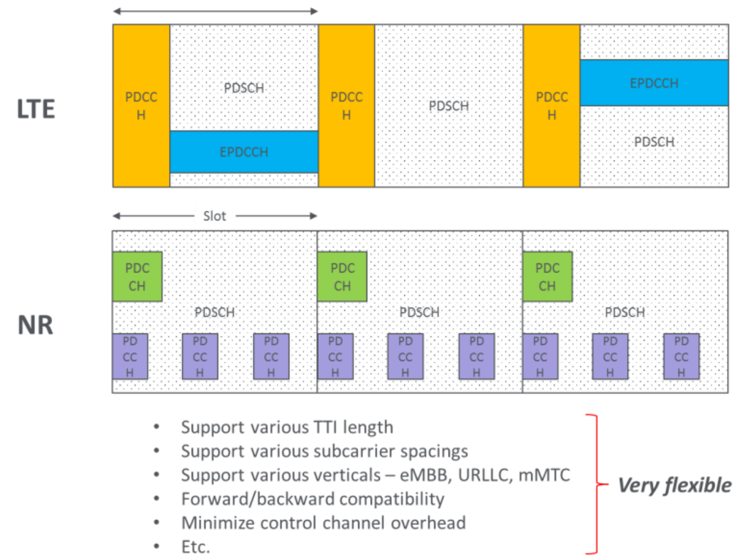
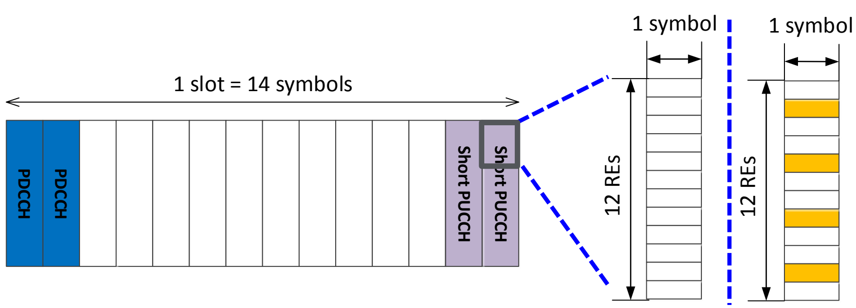
- **UE power saving by PDCCH monitoring with smaller bandwidth & flexible periodicity**

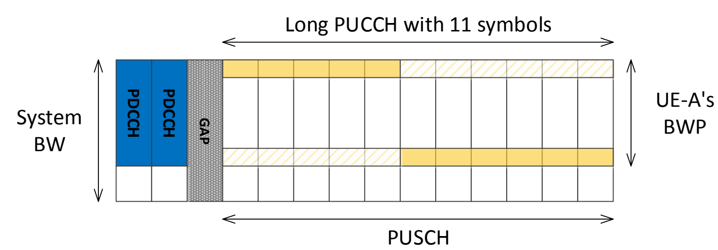


[CORESET: Control Resource Set]



- **Short PUCCH for latency reduction and long PUCCH for large coverage**

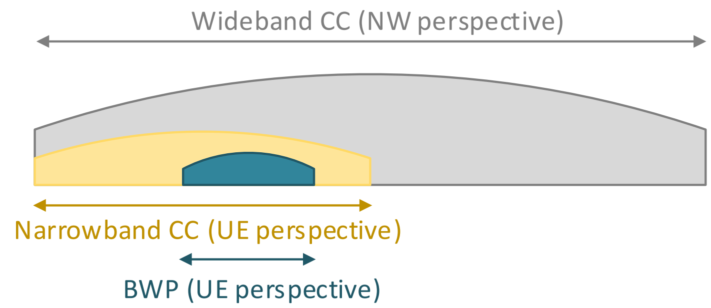




Bandwidth Part (BWP)

What is BWP?

- Group of contiguous PRBs
- PD(U)CCH/PD(U)SCH transmission/reception within a BWP
- Each BWP associated with a specific SCS and CP type
- BW size of BWP ≤ UE BW

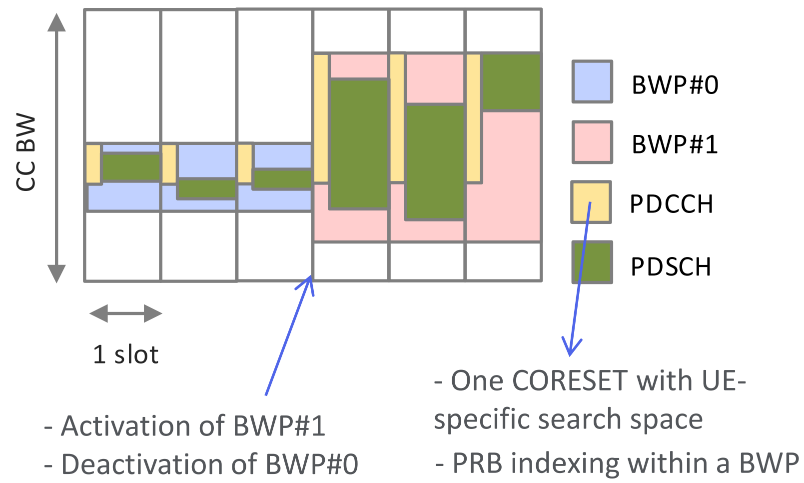


BWP configuration for each DL and UL

- One or multiple BWP configurable via RRC

BWP (de)activation

- Among configured BWPs, one BWP activated at a given time
- L1 (DCI) signaling
- Back to default BWP if timer expired



Beam Management

- **Identifying best Rx & Tx beams. Maintaining ‘N’ Candidate Beams for fast recovery.**

※ ① or ② or ①&②

①
SS block transmission → **Beam measurement**
Beam reporting ←

②
CSI-RS transmission → **Beam measurement**
Beam reporting ←

Beam indication →

Beam switch ↔ **Beam switch**

- Beam measurement : L1-RSRP
- Beam reporting : *N* selected beams and corresponding RSRPs
- Beam indication : QCL association based on SS block, CSI-RS resource index

UE operation to recover from beam failure

Beam failure detection
- When serving PDCCH fails (hypothetical BLER)

New candidate beam identification
- Based on L1-RSRP of configured CSI-RS or SS block

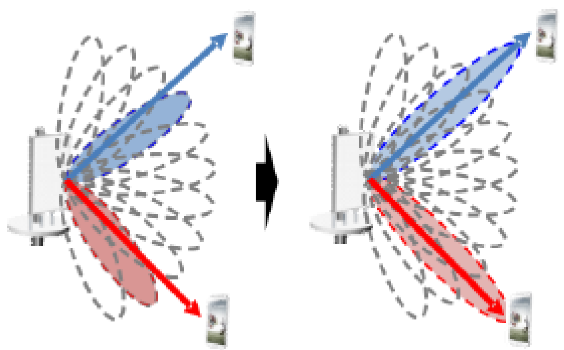
Beam failure recovery request transmission
- Contention-free sequence transmission at RACH resource
- RACH resource is associated with a new identified beam

Monitoring gNB response for recovery request

MIMO

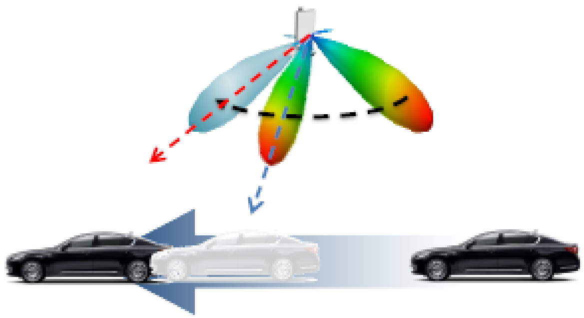
- NR-MIMO is the key technology to achieve 3 times the spectral efficiency of LTE-A
- Multi-beam-based operation to improve coverage for high frequency bands, e.g., 28 GHz

Advanced CSI



- LTE's CSI is not accurate enough to suppress MU interference
- NR's advanced CSI provides improvement for MU transmissions

Dynamic Adaptation to Velocity



- Dynamic adaptation between closed (low mobility) and open (high mobility) loop MIMO
- Open loop MIMO supported via cycling of different precodings

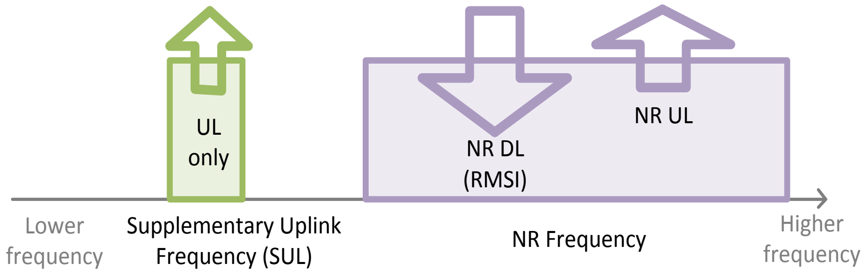
Beam Management

- UE indication of the best DL beam
- gNB indication of the beam direction for the UE to transmit or receive
- Beam failure report via L1 signaling

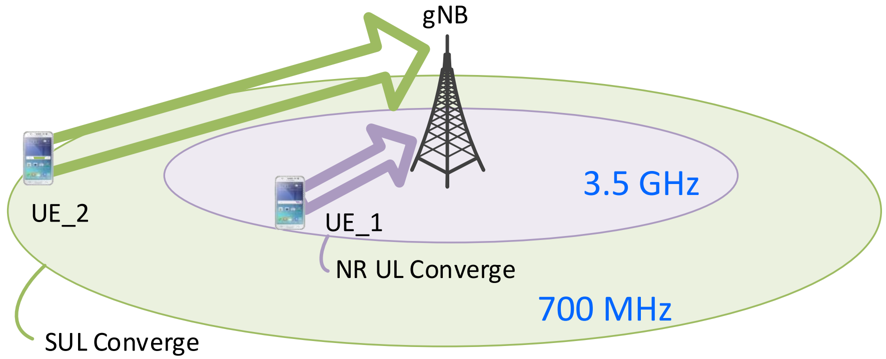
Supplementary Uplink

SUL in Lower Frequency to compensate UL Coverage Limitation of Higher Frequency Bands

- A cell is configured with one downlink carrier and 0/1/2 uplink carriers
- Initial Access via either normal UL or SUL based on the signal quality of the downlink
- PUCCH is configured only at one of the two uplinks
- PUSCH transmission is allowed only at one of the two uplinks indicated in UL grant



SUL configuration

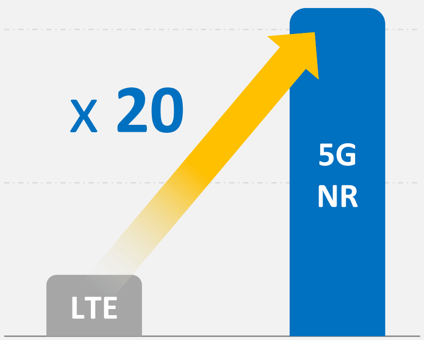


Example coverage of NR normal uplink and SUL

5G Performance Enhancements

Orders of Magnitude Enhancements Expected in 5G NR against 4G LTE-A Pro (Rel.13)

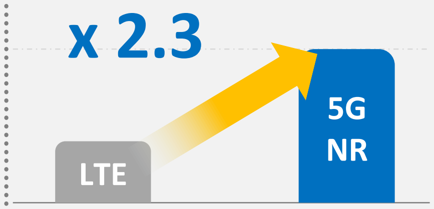
Peak Throughput



Wide bandwidth support

- Large chunk of spectrum for wideband at above-6GHz (e.g., 28GHz, 39GHz)

Spectral Efficiency



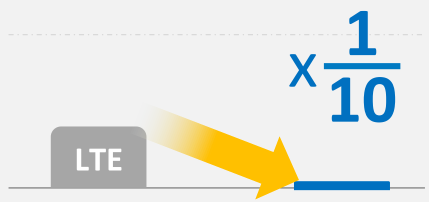
Lean System Design

- Reduced system overheads,

MIMO Enhancements

- Enhanced CSI feedback

Low Latency



Ultra low latency

- Latency reduction with shorter symbol duration
- Flexible HARQ operation and dynamic TDD

UE Energy Consumption

Reduced Power Consumption

- Inactive state reduced connection time
- Reduced always-ON signals
- Bandwidth Part

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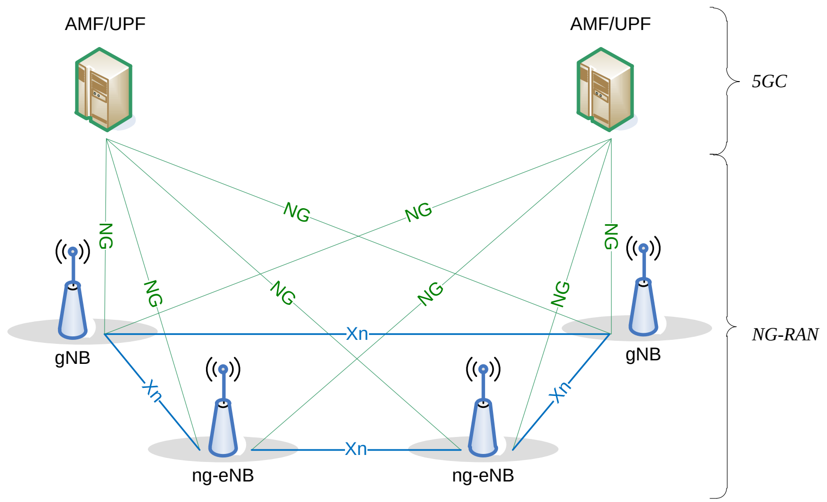
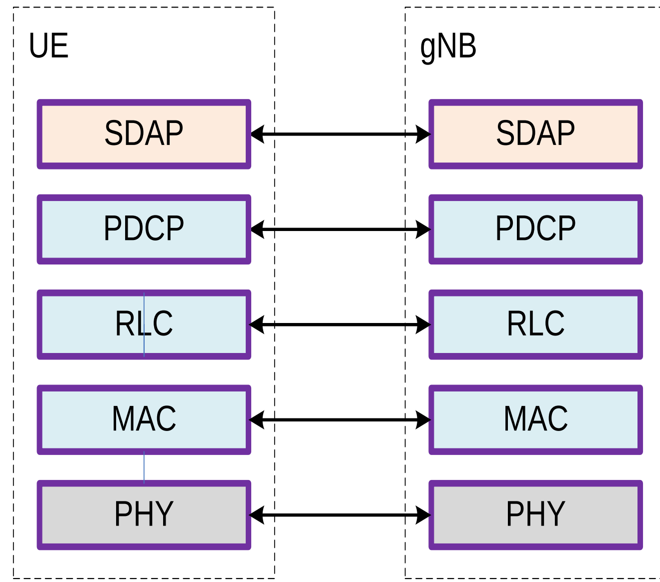
Ⅱ. 5G Radio Protocol

Radio Access Network Architecture and Protocol

Network Architecture



Radio Protocol



Changes compared to LTE Radio Protocol

NR SDAP

- Mapping of QoS Flow to Radio Bearer
- Different QoS Flows of same PDU session mapped to different Radio Bearers

NR PDCP

- PDCP Reordering and duplicate detection
- Retransmission of PDCP SDUs

NR RLC

- Concatenation of RLC SDUs is removed
- Reordering of RLC PDUs is removed

MAC

- Small change to logical channel prioritization due to multiple numerology support

Architectures for NR

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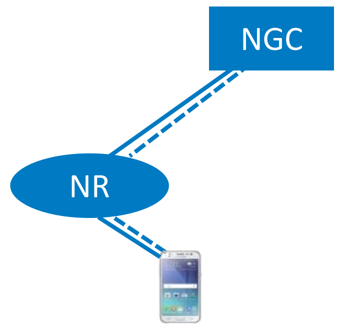
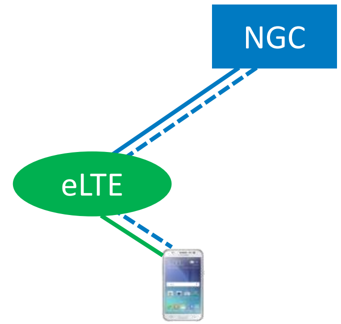
Standalone Architecture (SA) options

Rel-15 SA Phase 1 (June. 2018)



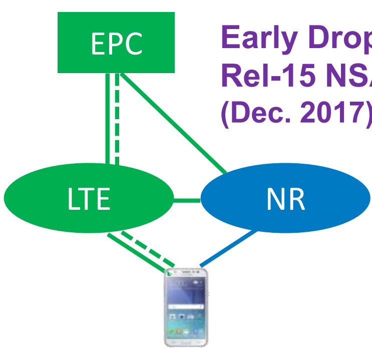
NR gNB connected to NextGen Core



Rel-15 SA Phase 1 (June. 2018)

Upgraded LTE eNB connected to NextGen Core

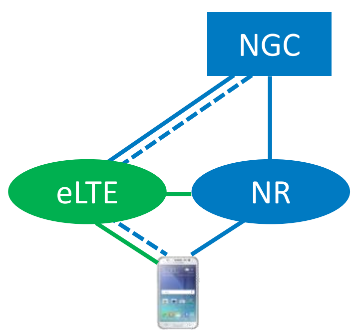
Non-Standalone Architecture (NSA) options



Early Drop Rel-15 NSA Phase 1 (Dec. 2017)

NSA EN-DC

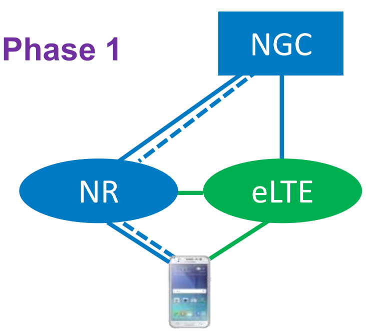
- Master Node – LTE
- Secondary Node - NR



NSA NG-EN-DC

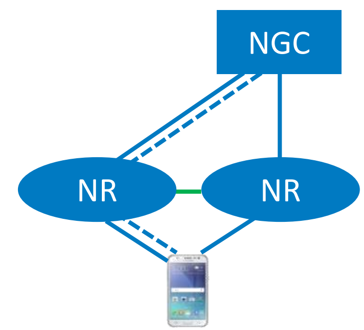
- Master Node : Upgraded LTE
- Secondary Node - NR

Late Drop Rel-15 NSA Phase 1 (Dec. 2018)



NSA NE-DC

- Master Node - NR
- Secondary Node - Upgraded LTE



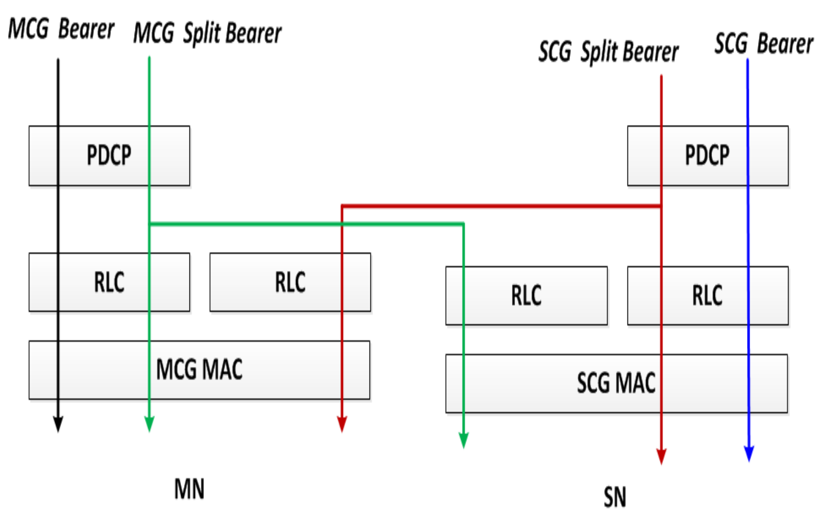
NSA NR-DC

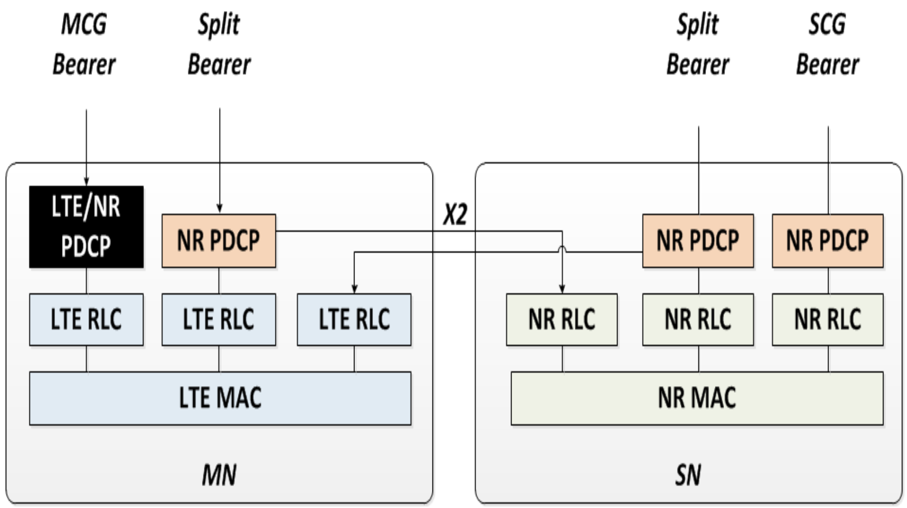
- Master Node - NR
- Secondary Node - NR

Radio Bearer Types

NSA supports various radio bearer configurations

- PDCP can be located at a network node different from RLC and MAC
- Radio bearers of LTE eNB can be configured with the new NR PDCP





Fast Packet Processing

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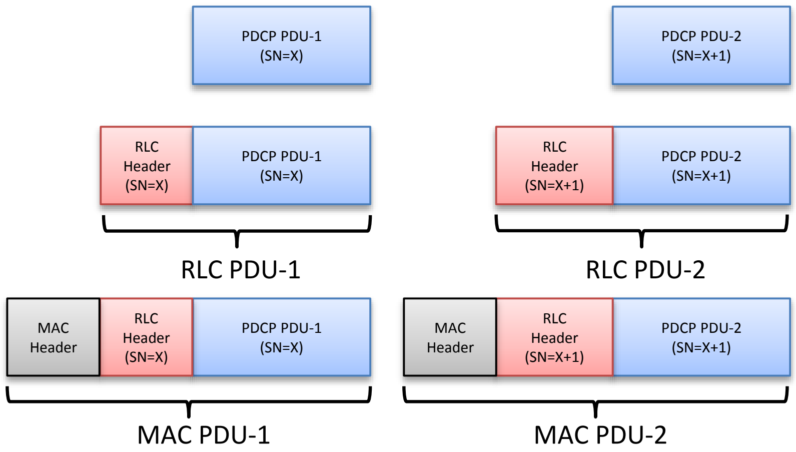

Pre-processing of data packets using no concatenation

Feature	LTE	NR	Benefits
Concatenation	Supported at: • RLC for per-bearer concatenation • MAC across RLC entities	Only supported at MAC	Removal of concatenation allows pre-processing of RLC headers without receiving UL grant
Segmentation	RLC segmentation of 2 types: • Different RLC segments assigned different SN • SO based segmentation	Only SO based segmentation supported	SO based segmentation preserves the RLC SN, hence pre-processed RLC headers do not change based on received grant size
Re-ordering / Duplicate Detection	Supported at: • RLC • PDCP for split bearer and HO	Only supported at PDCP (out of order RLC SDU delivery)	Immediate delivery of packets from RLC to PDCP, reduces processing burden on PDCP
MAC Header Construction	Fixed in front of MAC TB	Distributed in front of MAC SDU	NR MAC header placement results in simpler MAC hardware implementation

New Inactive State for UE

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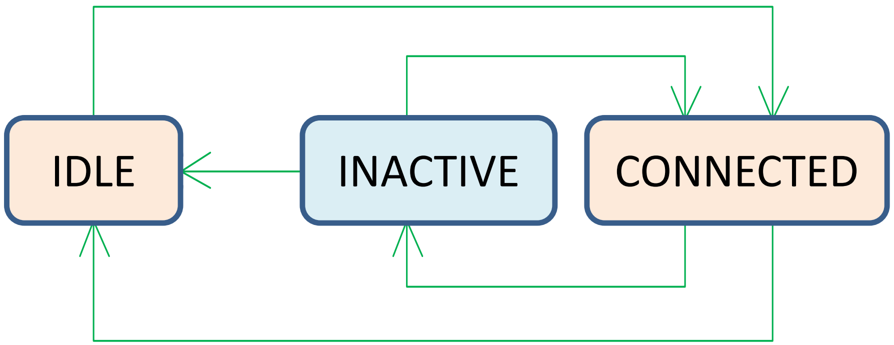
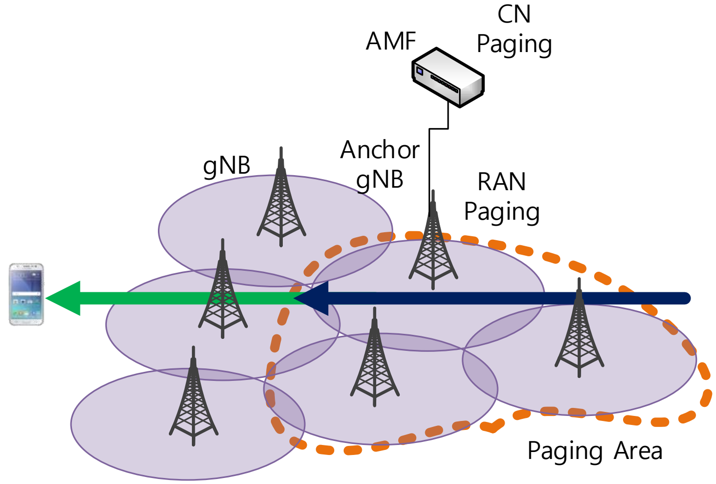
- **A new Inactive state minimizes overhead of connection establishment**
  - CN connection and radio bearer configurations are maintained
  - Radio connection and resource configurations are released
- **RAN-level paging is introduces to reach inactive UEs**
  - UE reselects cells within a RAN paging area without any notification to the network
  - Anchor gNB triggers RAN paging within the RAN paging area when UE data is arrived

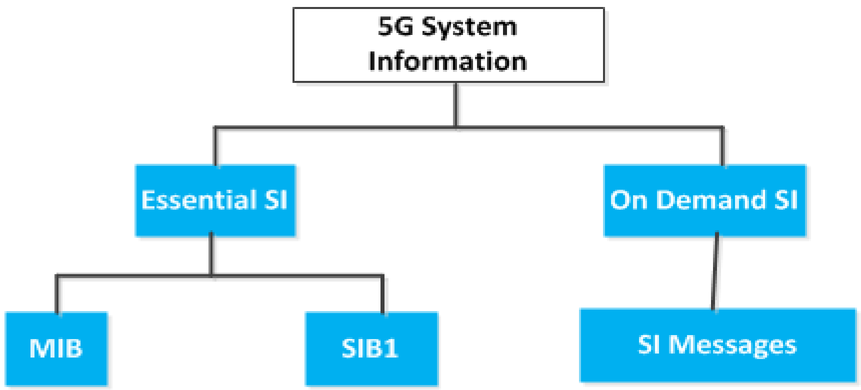




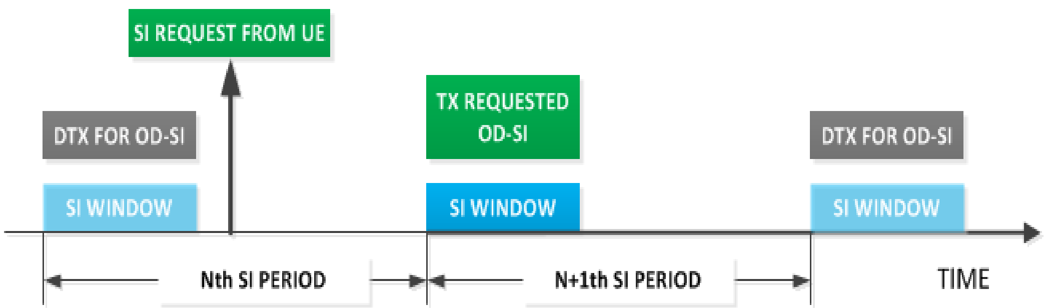
RAN paging area

On-demand SI Provisioning

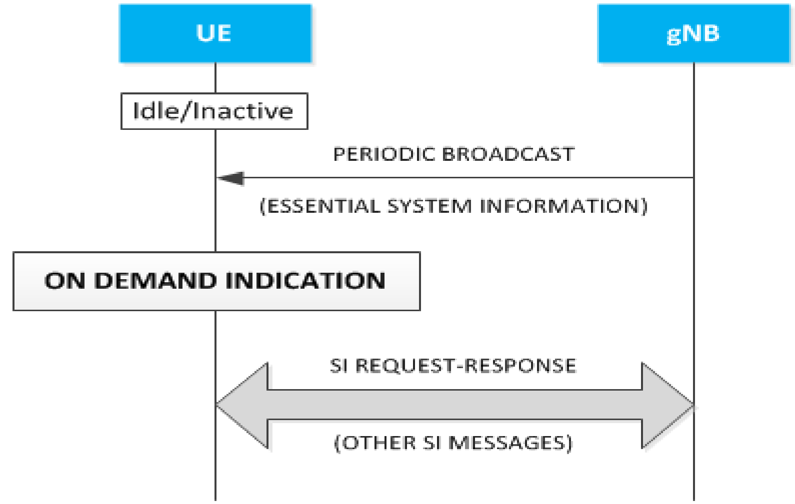
- Minimum SI (MIB & SIB1) periodically broadcasted
- Other SI (rest of SIBs) under NW control to be broadcasted or provided on UE request



SI Categorization



UE Request when SI needed



SI Broadcast based on UE Request

Summary of NR Radio Protocol Key Features

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	Feature	Description	Category
User Plane	Gbps data processing	- Simplified RLC layer (No concatenation and no reordering) - Dispersed MAC Sub-headers	RLC Concatenation, RLC Re-ordering
	Dynamic QoS	- New SDAP layer mapping QoS flows and radio bearers - Reflective QoS update in the UE	QoS control based on EPS bearer
	High Reliability	- Packet duplication for signaling and data	No packet duplication
Control Plane	On-demand System Info.	- System information transmission upon request from UE - SI request in RACH preamble (MSG1) or MSG3	Periodic transmission only
	Inactive State	- New inactive state where only radio connection is released (core network connection is maintained)	Similar to light connection
Mobility	High frequency beam-forming	- Measurement and random access procedures for beam-formed transmission	-
LTE Interworking	Dual RRC	- Independent LTE and NR RRCs (less coupling of eNB and gNB)	Single RRC
	Flexible Bearer	- Decoupling of PDCP and RLC/MAC location - LTE Data/Control Bearer over NR PDCP	PDCP Anchor @ MN only

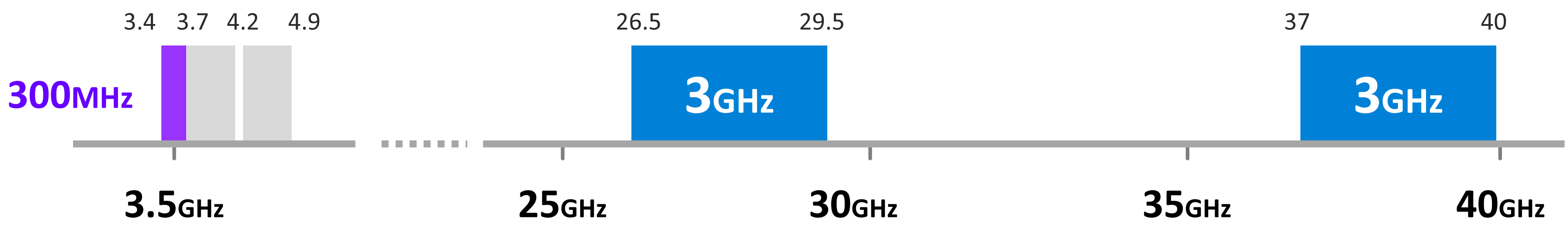
Ⅲ. 5G Spectrum

Candidate Frequencies

3.5GHz & 28GHz are Leading Candidates

Below 6GHz

Above 6GHz



Europe 3.4 - 3.8GHz

Korea 3.4 - 3.7GHz (300MHz)

Japan 3.6 - 4.2GHz, 4.4 - 4.9GHz

India 3.3 - 3.6GHz

Europe 24.25 - 27.5GHz

USA 27.5 - 28.35GHz (850MHz)

Korea 26.5 - 29.5GHz

Japan 27.5 - 29.5GHz

USA 37 - 40GHz (3GHz)

US FCC additionally allocated 24GHz (24.25-24.45 GHz and 24.75-25.25 GHz) and 47GHz (47.2-48.2 GHz) for 5G, Nov 2017

Global Trends on 5G mmWave Bands

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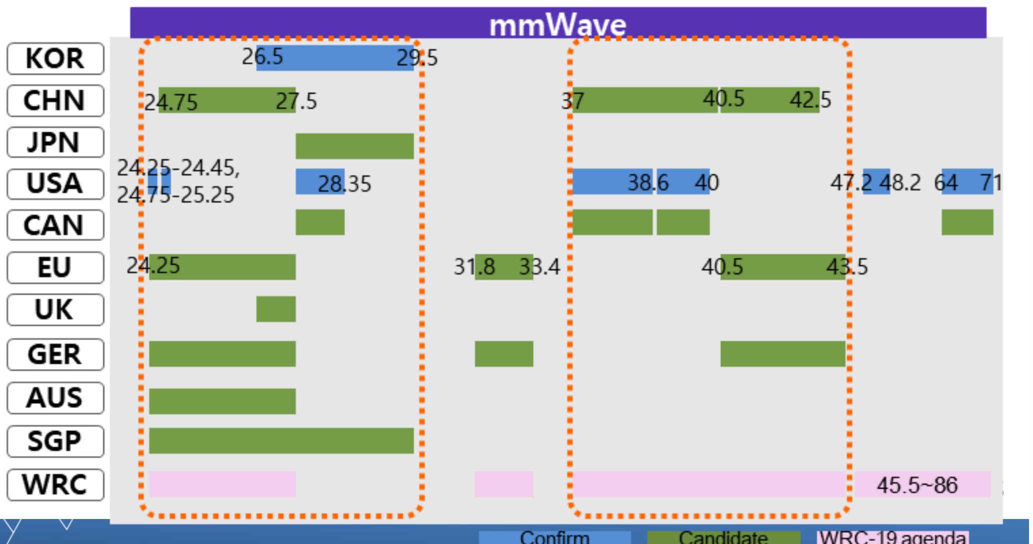
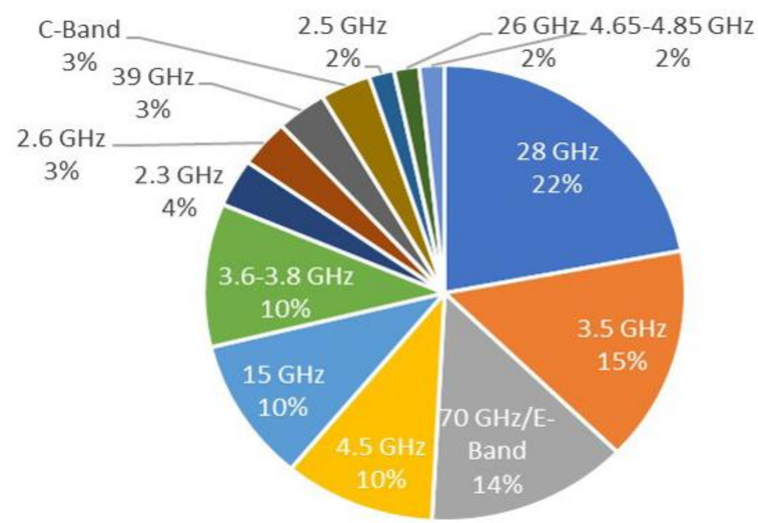
- **US**: FCC decided to provide 28GHz/38GHz/39GHz for 5G, July 2016 (added 24GHz/47GHz, Nov 2017)
  - Commercial services of 5G FWA and Mobile using 28 GHz in 2018 and 2019, respectively
- **Europe**: EC agreed that 26GHz should be ‘pioneer bands’ for 5G, Nov 2016
  - UK Ofcom proposed to release its upper band (26.5~27.5GHz) before WRC’19
- **Korea**: MSIP announced the plan to use 28GHz for 5G, Jan 2017
- **Japan**: MIC published the report where 5G candidate spectrum includes 28GHz, July 2016

[Global mmWave spectrum outlook for 5G]



[Distribution of 5G Trials; source GSA]



3GPP NR Band (RAN4)

- **Global operators are showing interest in 3.5GHz band (<6GHz) & 28GHz band (>6GHz)**

Category		Frequency Range	Supporting Operators
Above-6GHz		n260 (37~40.GHz)	AT&T, Verizon, T-mobile
		n257 (26.5~29.5GHz)	Verizon, T-mobile, KT, SKT, LGU+, docomo, KDDI, SBM, Orange, DT, BT, Telecom Italia, Telstra, CMCC, Etisalat
		n258 (24.25~27.5GHz)	Verizon, T-mobile, KT, SKT, LGU+, docomo, KDDI, SBM, Orange, DT, BT, Telecom Italia, Telstra, CMCC, Etisalat
		…	…
Below-6GHz	New Spectrum	n79 (4.4~5.0GHz)	Docomo, KDDI, SBM, CMCC, China Unicom, China Telecom
		n78 (3.3~3.8GHz)	Docomo, KDDI, SBM, CMCC, China Unicom, China Telecom, KT, SKT, LGU+, Orange, Telecom Italia, BT, DT, Etisalat
		n77 (3.3~4.2GHz)	Docomo, KDDI, SBM, CMCC, China Unicom, China Telecom, KT, SKT, LGU+, Orange, Telecom Italia, BT, DT, Etisalat
		…	…
	LTE Bands	Band40 (2.3GHz)	CMCC
		Band3 (1.8GHz)	China Telecom, China Unicom, CMCC, KT
		Band5 (850MHz)	AT&T
		…	…

TRAI Recommendation on Spectrum

SAMSUNG Research

TRAI Recommendations, Aug 2018

TRAI

- **Entire available spectrum below 6 GHz bands** (i.e. 700 MHz, 800, MHz 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500 MHz, 3300- 3600 MHz bands) should be put to auction.

- Approximately **60 MHz FDD spectrum** and **340 MHz TDD** spectrum available for auction
  - 2x35 MHz FDD spectrum from 700 MHz band available for auction
  - **275-300** MHz TDD from 3.3 – 3.6 GHz available for auction
  - Spectrum harmonization needed in 2300 MHz TDD band for efficient utilization

- **3.3 – 3.6 GHz** should be auctioned as **single TDD band** with a **minimum block size of 20 MHz** (unpaired) and a cap of 100 MHz per TSP

5G High Level Forum Recommendation on Spectrum

SAMSUNG Research

HLF Recommendation, Aug 2018

- **Announce Tier** – Bands declared for 5G rollout
  - 698-803 MHz, 3300-3600 MHz, 24.25-27.5 GHz, and 27.5 – 29.5 GHz.
  - The two mmwave Bands should be opened free for two years to support rollout trials and indigenous R&D.
- **Identify Tier** – Bands designated for potential 5G
  - 617-698 MHz, 1427-1518 MHz, 29.5 to 31.3 GHz and 37.0 to 43.5 GHz.
  - The 37.0 to 43.5 GHz bands should be opened free for two years to support indigenous R&D.
- **Study Tier** – Bands designated for 5G usage studies.
  - These bands should be considered as only of potential availability for 5G networks [3600-3700 MHz]

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IV. 5G India Considerations

a. Migration Path

b. Wideband NR vs CA LTE in 3.5GHz

c. 3.5GHz Uplink Coverage

5G Migration Paths

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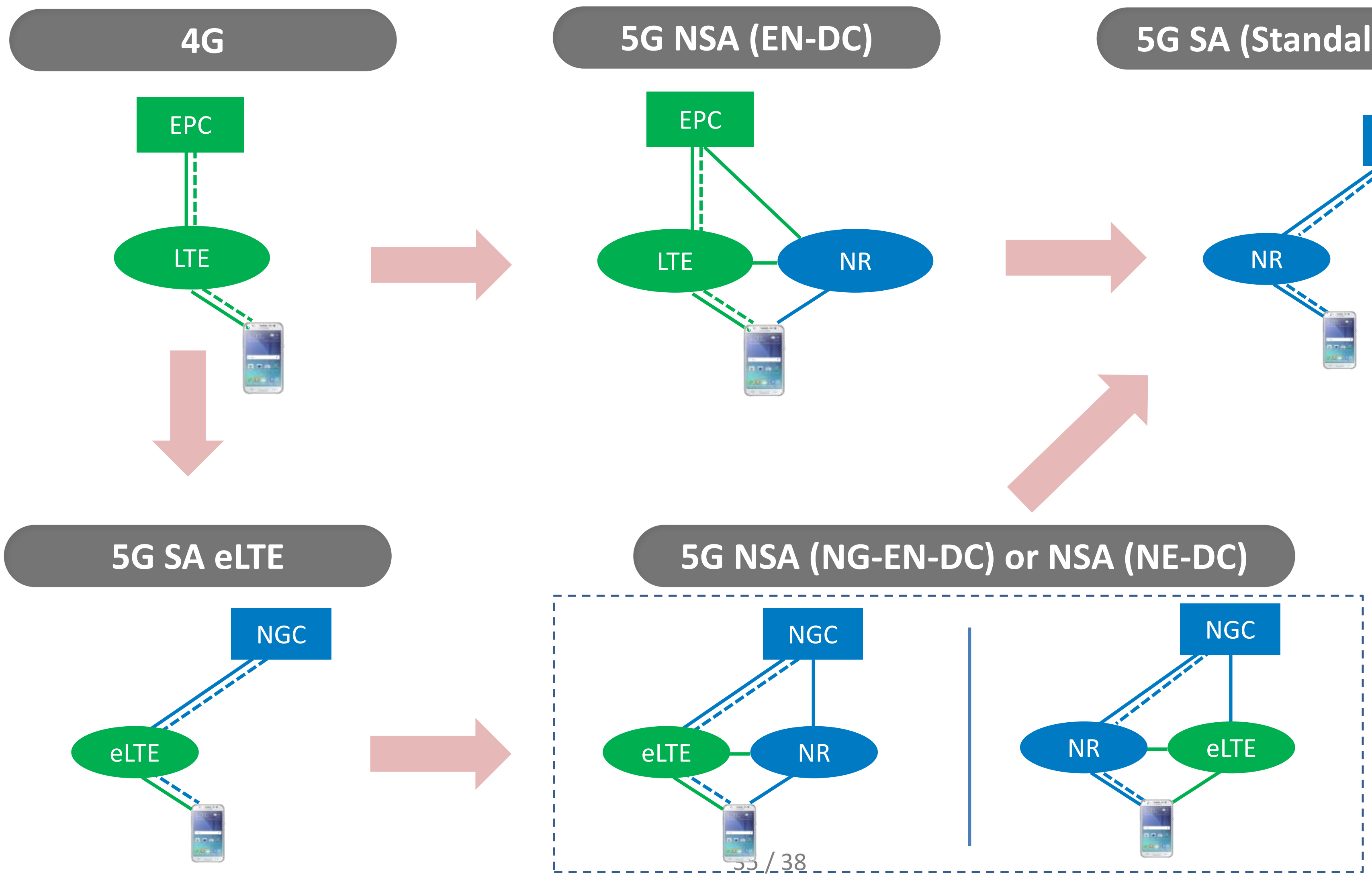

3.5GHz: NR or LTE

- **Wideband NR is expected to provide 25-28% DL throughput gain over CA LTE**
  - Most of gain comes from more efficient RB utilization and overhead reduction using large band

	NR T-put gain over LTE
PDCCH Overhead	2-5%
RB utilization / other Overhead (1)	22.36%
NR Gain over LTE	**25%-28%**

(1) : Available DL resources considering RB utilization and control/RS overhead

- **3.5GHz with higher MIMO configuration using NR could have similar UL coverage with 2.3GHz 4T4R LTE**

- **3.5GHz has no uplink coverage issue if it is co-sited with 2.3GHz 4T4R**

  for the same link performance, system overhead and same target data rate

- **3.5GHz NR can have better system performance than 2.3GHz LTE**

  because of efficient resource utilization as explained earlier

* Assumed to be 25%

28 GHz Measurements & Results

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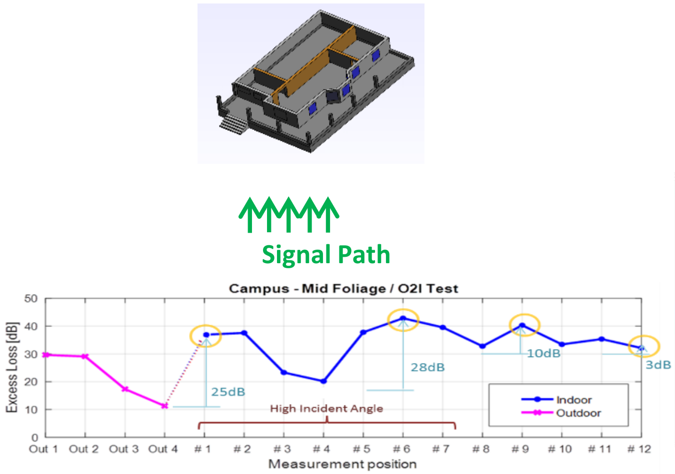
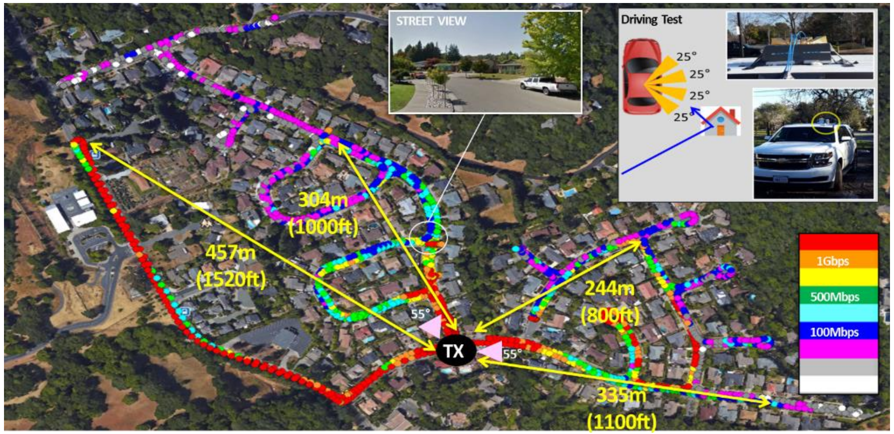
- Rain attenuation is not trivial but manageable
- Atmospheric Loss due to H_2O & O_2 is Negligible for 28/39 GHz, but Huge for 60 GHz
- 28 GHz Foliage loss increases "not linearly" along the depth of foliage





- 28 GHz Window O2I Loss Ranges from 3dB to 28dB depending on Incident Angle
- Coverage Estimation : 244m to 457m for NLOS Locations

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धन्यवाद!

Contact: Suresh Chitturi
Email ID: s.chitturi@samsung.com

Contact: Anshuman Nigam
Email ID: anshun@samsung.com

Contact: Mangesh Ingale
Email ID: m.ingale@samsung.com

Contact: Diwakar Sharma
Email ID: diwakar@samsung.com