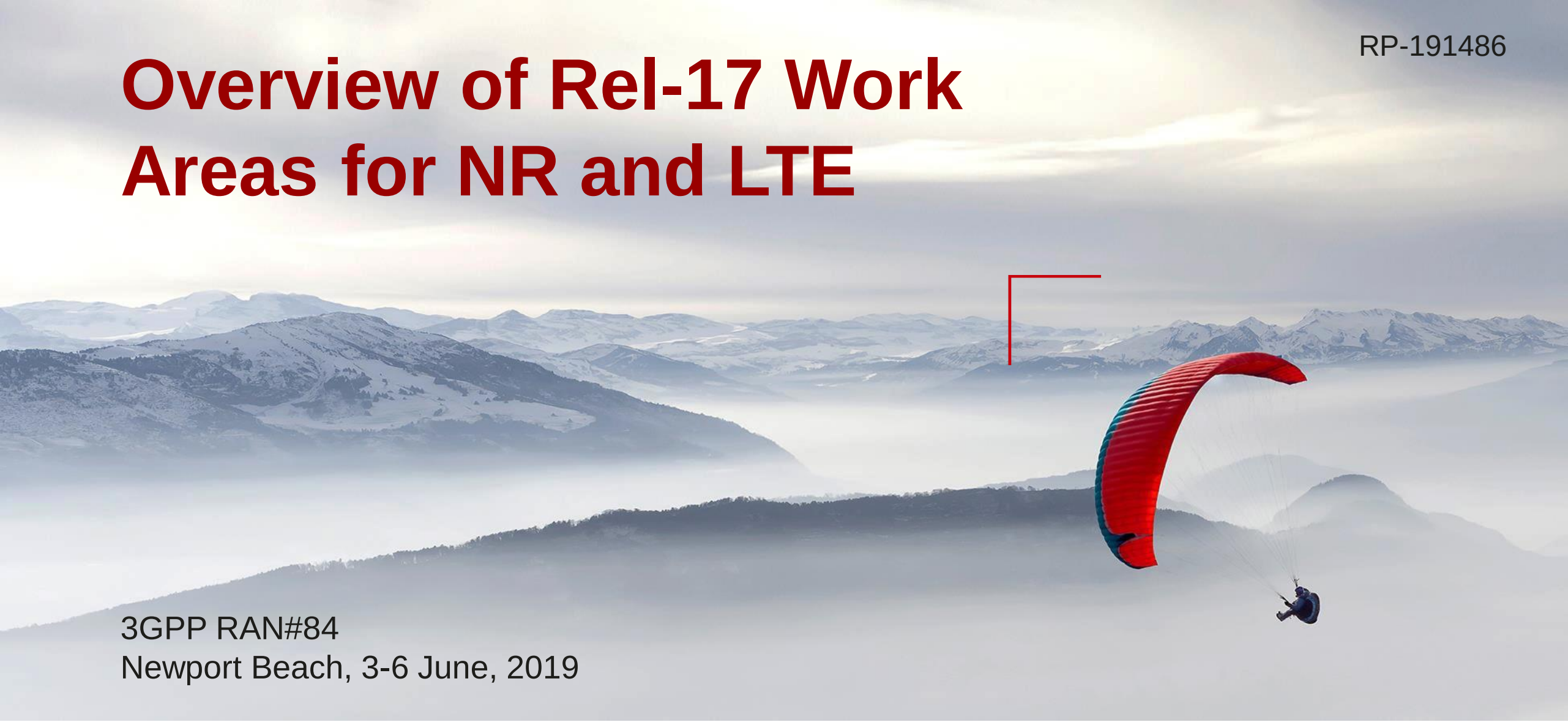
RP-191486

Overview of Rel-17 Work Areas for NR and LTE



3GPP RAN#84
Newport Beach, 3-6 June, 2019

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Key Rel-17 NR Enhancements

Sub-3GHz FDD enhancements

- FDD partial channel reciprocity for MIMO
- Efficient multi-carrier operation

Coverage and UL enhancements

- Indoor coverage enhancements
- UL capacity enhancements (e.g. WTTc)

Sidelink enhancements

- Sidelink performance enh (V2X enh)
- Sidelink UE relays
- Sidelink UE cooperation

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Proposed Work Areas

- **NR sub 3-GHz FDD enhancements**
  - FDD spectral efficiency enhancements via FDD channel partial reciprocity, efficient multi-carrier operation with control overhead reduction
- **Coverage and uplink enhancements for NR and LTE**
  - Indoor coverage enhancements, uplink capacity enhancements (WTTc for wireless video cameras), potential enhancements for rural and extreme coverage
- **NR sidelink enhancements for V2X and other use cases**
  - Sidelink performance enhancements for V2X and other use cases such as AR/VR, sidelink UE to network relay and UE cooperation
- **NR URLLC & Industrial IoT**
  - Covering distributed machine controllers for factories, enhancement of standalone NPN , URLLC capacity for factories, etc
- **NR Multicast and Broadcast Services**
  - Mixed-mode dynamic multicast/unicast aligned with SA2 study, including support of V2X Uu multicast
- **Enhanced support for Dual SIM UEs**
  - LTE+EN-DC dual-SIM UE, LTE+NR SA dual-SIM UE and NR+NR dual-SIM UE
- **Intelligent Networks (SON/MDT enhancements)**
  - Continuation of Rel-16 RAN-centric data collection, can also consider network energy efficiency
- **NR MIMO TDD enhancements**
  - SRS enhancements for massive-MIMO mobility, non-linear precoding, FR2 and beam management enhancement
- **Mobility enhancements**
  - Scenarios: EN-DC enhancements, Direct HO to EN-DC
- **RAN slicing**
  - Slicing-specific mobility, Slice-specific data transmission with less signaling overhead
- **QoE enhancements**
  - Support QoE for more services, short-term and real-time
- **NR-MTC enhancements**
  - UE capability relaxation for MTC UEs (no reduction of UE min bandwidth) (WTTc). Transmission in RRC_INACTIVE state with large number of connections (IWSN).
- **NB-IoT enhancements**
  - Latency reduction, IoT relay based on Uu, efficiency enhancements
- **LTE eMBB enhancements**
  - MIMO CSI, WTTx optimizations, more CA band combinations
- **NR full duplex radio**
  - Feasibility study of full duplex radio at the network side
- **Non-Terrestrial Networks**
  - For MBB in LEO and GEO deployments
- **Study for frequencies above 52.6 GHz**
  - Waveform selection in Rel-17, signals/channels design in Rel-18
- **Integrated Access and Backhaul enhancements**
  - FDM/SDM, cross-link interference mitigation, 256 QAM, Potential Rel-16 leftovers (e.g. inactive mode), IRAT IAB
- **NR UE power savings enhancements**
  - Potential Rel-16 leftovers, possibly additional enhancements

Some of the areas above are detailed in the next slides

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Sub-3GHz FDD enh – FDD MIMO with partial channel reciprocity

Motivation

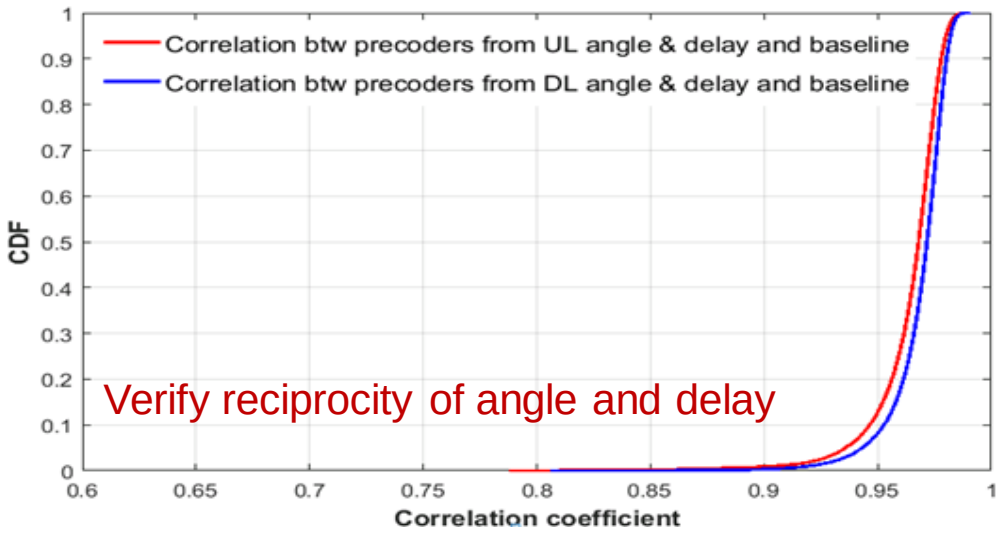
Further enhancement of NR FDD MIMO to facilitate sub-3GHz re-farming to NR by considering FDD partial channel reciprocity

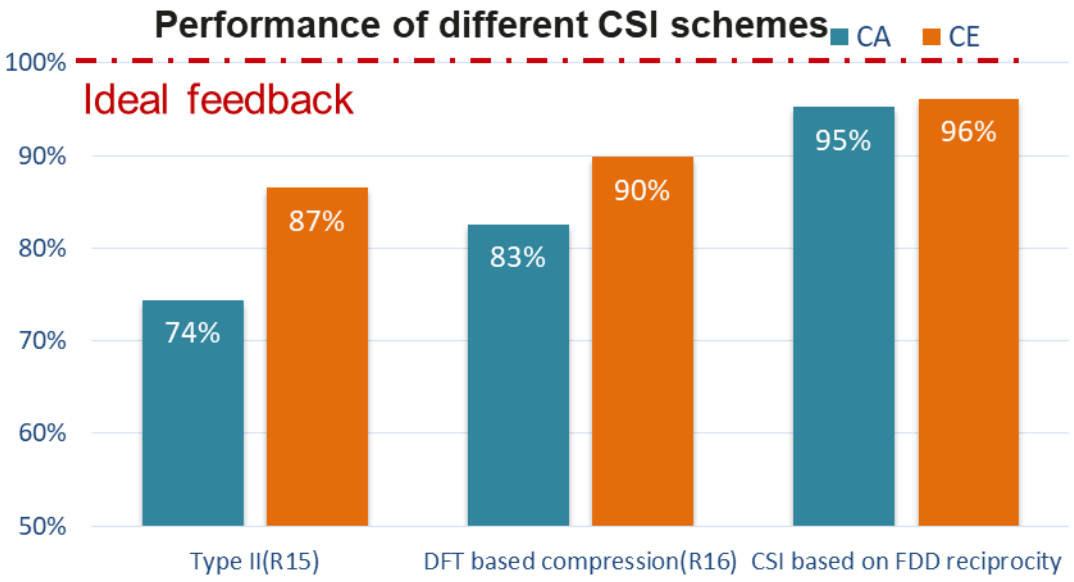
FDD channel have partial reciprocity

Channel property		Reciprocity
Instantaneous	Angle	Yes
	Delay	Yes
Statistic	Covariance matrix	Yes
	Angle power spectrum	Yes

Rel-15/Rel-16 CSI enhancement based on FDD partial reciprocity

e.g. Rel-15/Rel-16 port selection codebook enhancement based on FDD partial delay and angle reciprocity





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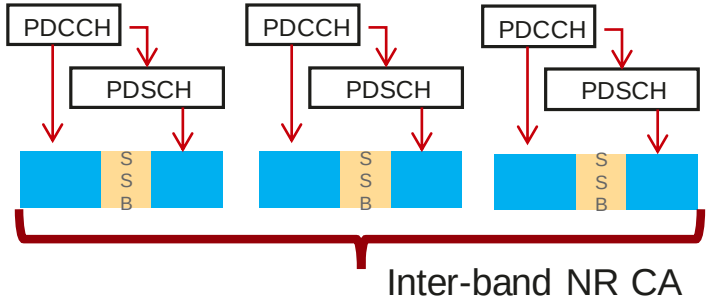
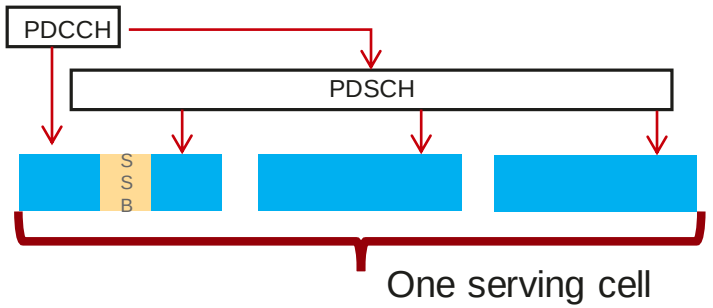
Sub-3GHz FDD enh – Efficient Multi-Carrier Operation

There are many intra-band and inter-band scattered spectrums in 700/800/900/1800/2100MHz band.

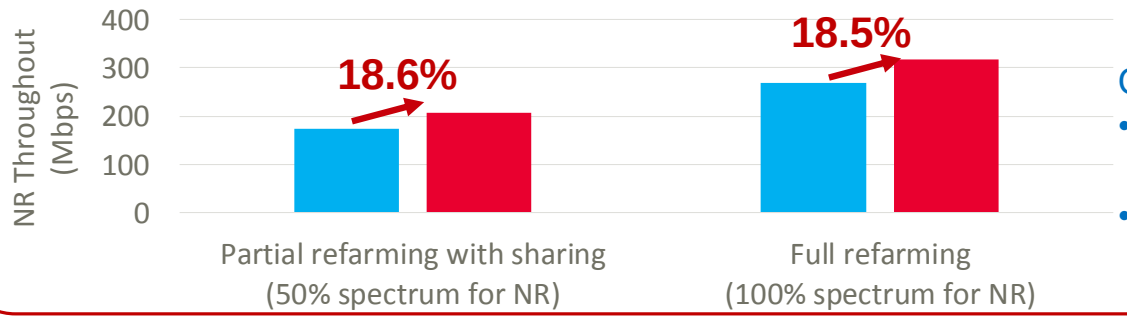
Parameters	Assumption
Carrier frequency and bandwidth	900MHz band: 10M; 800MHz band: 10M; 700MHz band: 10M.
SCS	15kHz
Inter-site distance	1000m
Channel model	SCM-UMI-3D
Total trans. power	43dBm
SSB Period	5ms
BLER of PDCCH	1%
IBLER of PDSCH	10%
Traffic model	Full buffer
Scheduling algorithm	PF
NR UE number per cell	12
UE speed	3km/h



- More NR spectrum from partial (sharing) or full refarming
- One PDCCH/PDSCH per cell ➔ high DL control overhead
- NR SSB Tx on every cell ➔ high common channel overhead



- One PDCCH/PDSCH across all three bands
- NR SSB only on one carrier
- Logical wideband operation



Gain comes from
- PDCCH/SSB overhead reduction
- PDSCH diversity/coding gain

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Motivation for Uplink Coverage Enhancements

Indoor coverage

- Indoor users suffer from large penetration loss

Frequency	Glass	Brick	Concrete
Sub3G	7~12dB	10~15 dB	20~25 dB
C-Band	10~15dB	15~23dB	28~38 dB
mmWave	15~21dB	35~53dB	65~79 dB

Remote coverage

- Support basic data speeds and voice services for long range coverage (up to 100 km) in low density areas (up to 2 user/km^2)
- Up to 1 Mbps in the downlink, and 100 kbps in the uplink

Uplink throughput/capacity

1080P：~4Mbps

2K：10Mbps

4K：25Mbps@2D
50Mbps@3D

- Newly emerging video services driven by surveillance cameras have large demanding on the uplink throughput
- Current uplink data rate for both cell average and per link is lower than the requirements

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NR Coverage Enhancement

Indoor coverage

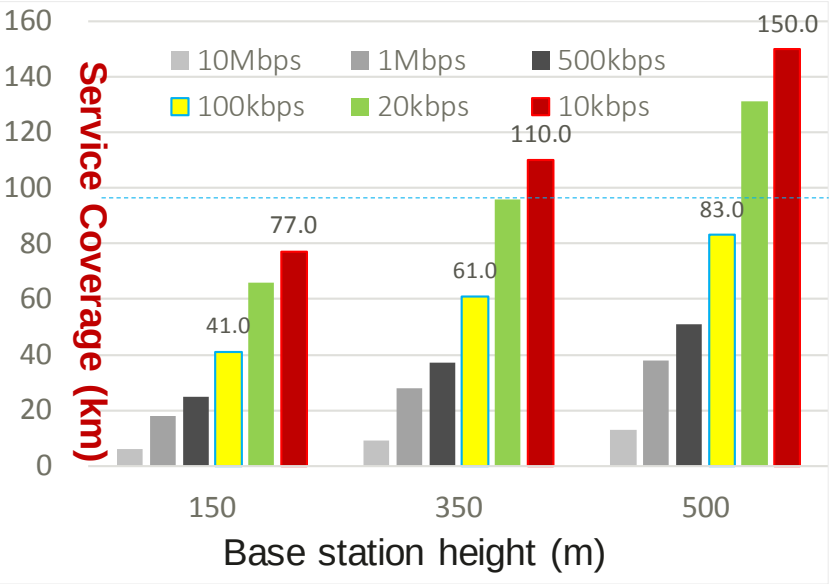
Frequency (GHz)	Penetration loss	Path loss difference (dB)
0.7	10.23	0.00
1.8	11.64	8.20
3.5	12.69	13.98
4.9	13.13	16.90

Typical TDD configuration DL:UL = 4:1

NR DL	NR DL	NR DL	NR DL	NR UL	NR DL	NR DL	NR DL	NR DL	NR UL

- Uplink coverage is limited in indoor area
  - Higher frequency has higher path loss and penetration loss
  - Small fraction of resource is used for uplink
  - Uplink transmission power is much lower than downlink

Long distance coverage of field testing



- Long distance coverage requirements from TS22.261
  - The 5G system shall support the extreme long range coverage (up to 100 km) in low density areas (up to 2 user/km2).
  - The 5G system shall support a minimum user throughput of 1 Mbps on DL and 100 kbps on UL at the edge of coverage.

Video surveillance

scenarios	UL data rate
Video surveillance for safe city/village	60~200 cameras per km²/cell, 2~4Mbps per camera
Factory supervising	6 video cameras for 1700 m², 100Mbps per camera
Fish farm monitoring	24~30 cameras per cell, 25Mbps per camera

- Video surveillance industry with massive connections is an emerging business opportunity for wireless communications.
- In 2016, the number of surveillance cameras in operation reached 200 million, and it is expected to reach 500 million by 2021.

- Potential uplink coverage enhancements
  - high power UE
  - cross slot channel estimation
  - techniques utilizing frequency diversity
  - UE cooperation
  - optimized scheduling/HARQ mechanism,
  - overhead reduction for slow-varying channels
  - enhanced UL power control and reusing the LTE-M/NB-IOT techniques etc.

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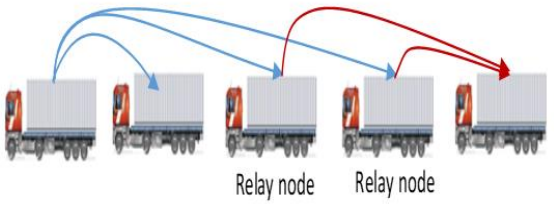
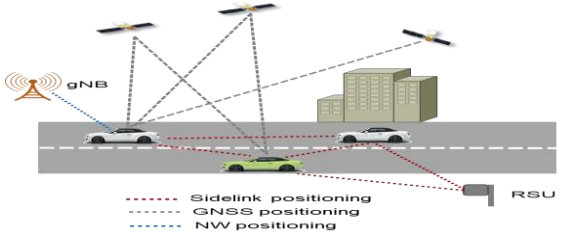
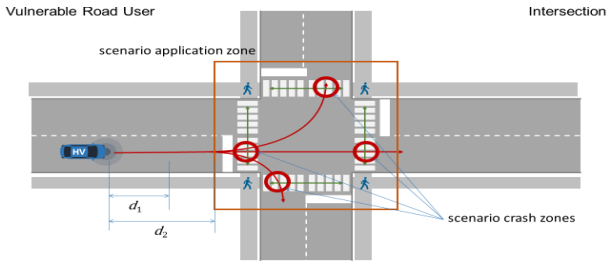
Sidelink Enhancements for C-V2X and Other Use Cases

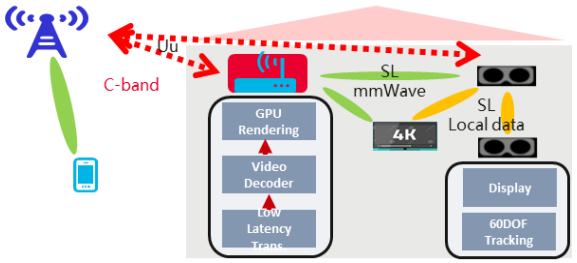
Motivation

- Sidelink communication range extension
  - Long vehicle platooning, e.g. 20 vehicles
  - Extended sensors with higher level-of-automation requires 1 km range
- Sidelink throughput burst
  - Extended sensors with higher level-of-automation requires 1Gbps data rate
- Sidelink high achievability
  - Satisfy QoS requirements for all UEs in very dense UE deployments
- Vulnerable Road User (VRU) and dynamic ride sharing
- SL relative positioning for 'cm' level accuracy



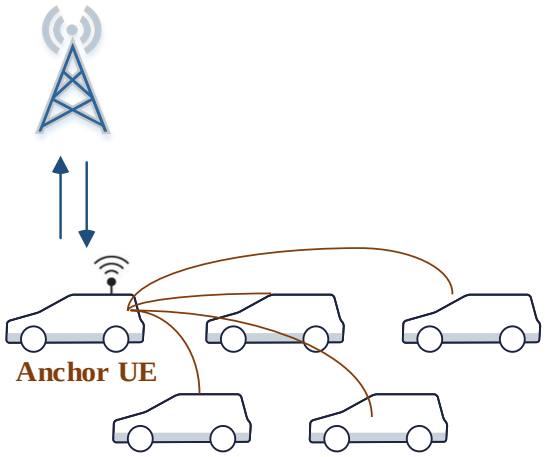


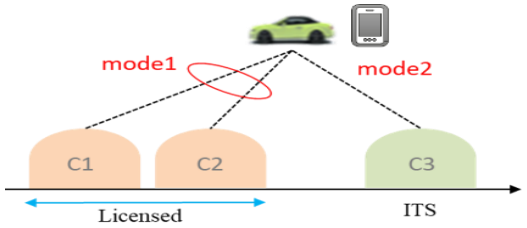




Technologies

- Relay framework: anchor based on sidelink resource allocation Mode 2d for coverage extension
- Sidelink spectrum efficiency improvement for throughput burst and high achievability
  - Sidelink carrier aggregation
  - Sidelink FR2 enhancement
  - Sidelink MIMO enhancements and high order modulation
- Power saving for V2P communication support.
  - DRX and partial sensing
  - Sidelink inactive state
- Sidelink relative positioning architectural, measurements, and procedures





Sidelink can be used for use cases other than C-V2X, e.g. proximity services for public safety, and interactive AR/VR services

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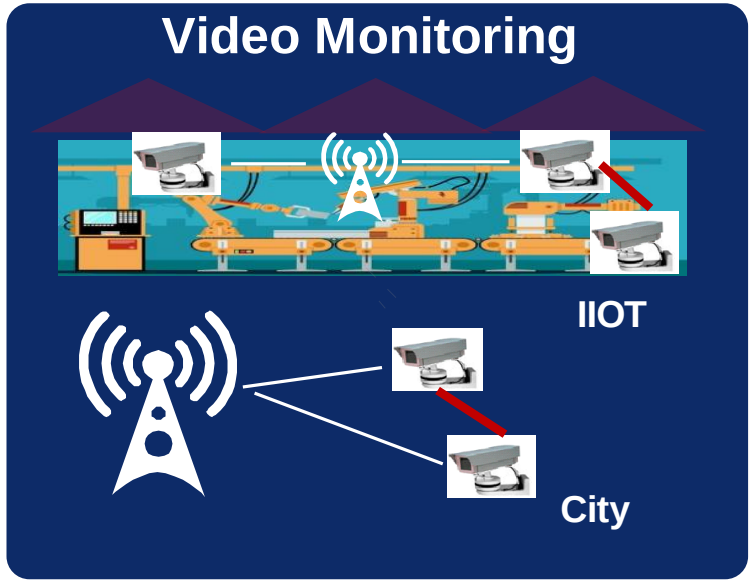
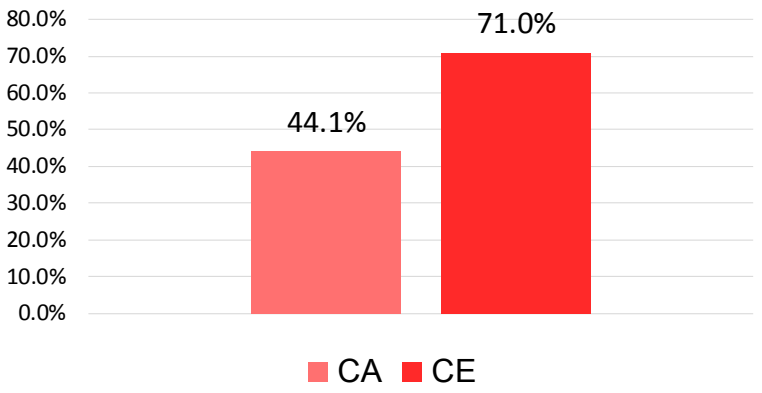
Network Assisted UE Cooperation (NAUC)



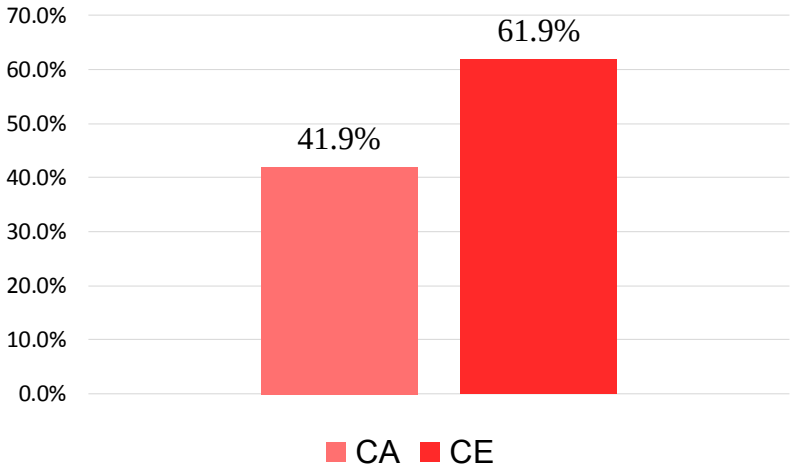
UC throughput gain with 1 CUE helping 1 SUE @ UL outdoor

UL



UC throughput gain with 1 CUE outdoor helping 1 TUE indoor @ DL

DL



Key technical components

- Discovery and grouping at RAN level
- Support source ID/destination ID for UC
- Intra-group transmission (SL): based on V2X SL resource allocation and transmission
- Data splitting/reassembling for UL UC transmission
- UE relay architecture
- Cooperated HARQ

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Rel-17 URLLC & IIoT

Motivation

- Gap still exists between achievable system availability in NR R16 and availability requirement in TS 22.104
- Hierarchical topology of IIoT production line, including line controller, machine controller and devices; three main requirements of machine controller
  - I. Local terminated data: motion control can be distributed and fully control local communication
  - II. Short delay: motion control requests for 0.5ms-2ms cycle time and 6-8^9 reliability (TS 22.104)
  - III. High dense eURLLC connections: up to 100 connections in a cell of 50*10*10m (TS 22.104)

Table Availability evaluation for URLLC & IIoT use cases

Differential Protection in Power Distribution

	FDD & 10 UE	TDD, DDDSU & 5UE
DL	100%	100%
UL	91.9%	49.5%

Remote Driving

	FDD & 10 UE	TDD, SUDSU & 5UE
DL	100%	96.7%
UL	85%	3.3%

*** Urban Macro for DP and V2X: ISD 500m, 4GHz & 40MHz, 16T/16R, FDD and TDD**

ARVR

	4096B & 10 UE	10K & 10 UE
DL	100%	67.5%
UL	91.7%	0%

Motion Control in Factory Automation

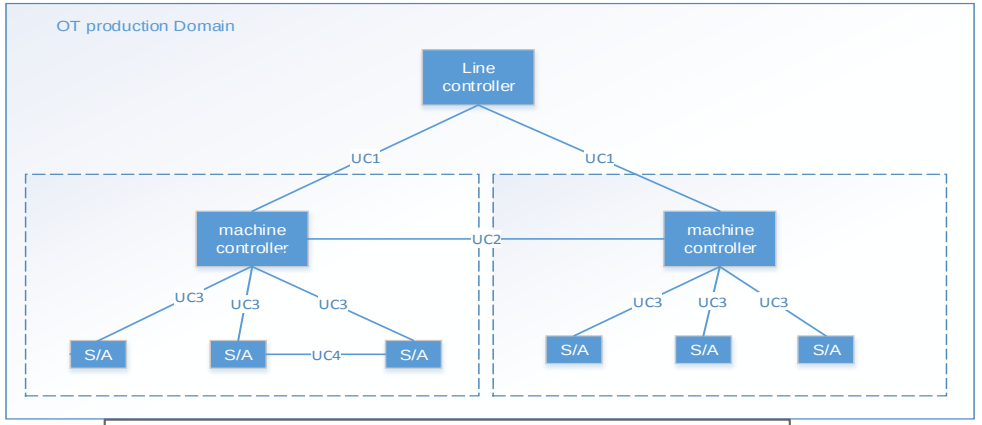
	20 UEs per cell	40 UEs per cell
DL	98%	74%
UL	68%	41%

*** Indoor for AR/VR and factory: ISD 20m, 4GHz & 40MHz, 4T/4R, FDD**

Potential work scope for NR Rel-17 URLLC & IIoT

- Enhancements for FR1 and FR2 for high data rate and high UE density
  - Robust beam management, reduce HARQ feedback delay for CA of FR1 and FR2, etc.
- Enhancements for improving system availability and efficiency
  - Aperiodic CSI on PUCCH, early termination by explicit ACK for UL CG, SPS/CG enhancements with channel adaptation, PHY repetition on carriers, scheduling and HARQ enhancements for closed-loop applications, interference management for different slot configurations between outside and inside factory
- The mechanism catering for distributed machine controller.
  - Study the hierarchical 5G architecture catering for hierarchical topology of industry production line;
  - Study the role of the distributed machine controller (e.g. UE type vs. network node type); support the local terminated service with stringent latency requirement; Industrial Ethernet integration, e.g., support for TSN in hierarchical 5G architecture
- Enhancements for non public network
  - Service continuity and RAN sharing between NPN and PLMN

Hierarchical topology of IIoT production line with distributed machine controllers



Four use cases in IIoT
- UC1: Line controller to machine Controller (L2C)
- UC2: machine Controller to machine Controller (C2C)
- UC3: machine Controller to field Devices (C2D)
- UC4: field Devices to field Devices (D2D)

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NR MTC

	Motivation	Design Targets
NR MTC	Enable new IoT and MTC markets beyond LPWA	**New Market #1: Video Surveillance** • Large number of cameras uploading with several Mbps everywhere in a cell • New UE capability: medium to high end MTC device without changing the minimum bandwidth (5MHz or 10MHz) to reduce cost and power consumption **New Market #2: Industrial Wireless Sensor Networks (IWSN)** • Varied sensors collecting data in factories and logistics • Larger number of connections in local areas with more frequent packet arrivals • Low overhead and power/resource efficient transmission in RRC_INACTIVE state

- **NR-MTC** will be studied in parallel with NB-IoT evolution to enable new **non-LPWA** markets and new requirements such as video surveillance and Industrial Wireless Sensor Networks (IWSN)
  - New UE capability for medium to high end MTC devices
  - Enhanced stationary wireless link for video monitoring service
  - Direct small data transmission in RRC_INACTIVE state
  - Enhanced UL configured grant transmission in RRC_CONNECTED state

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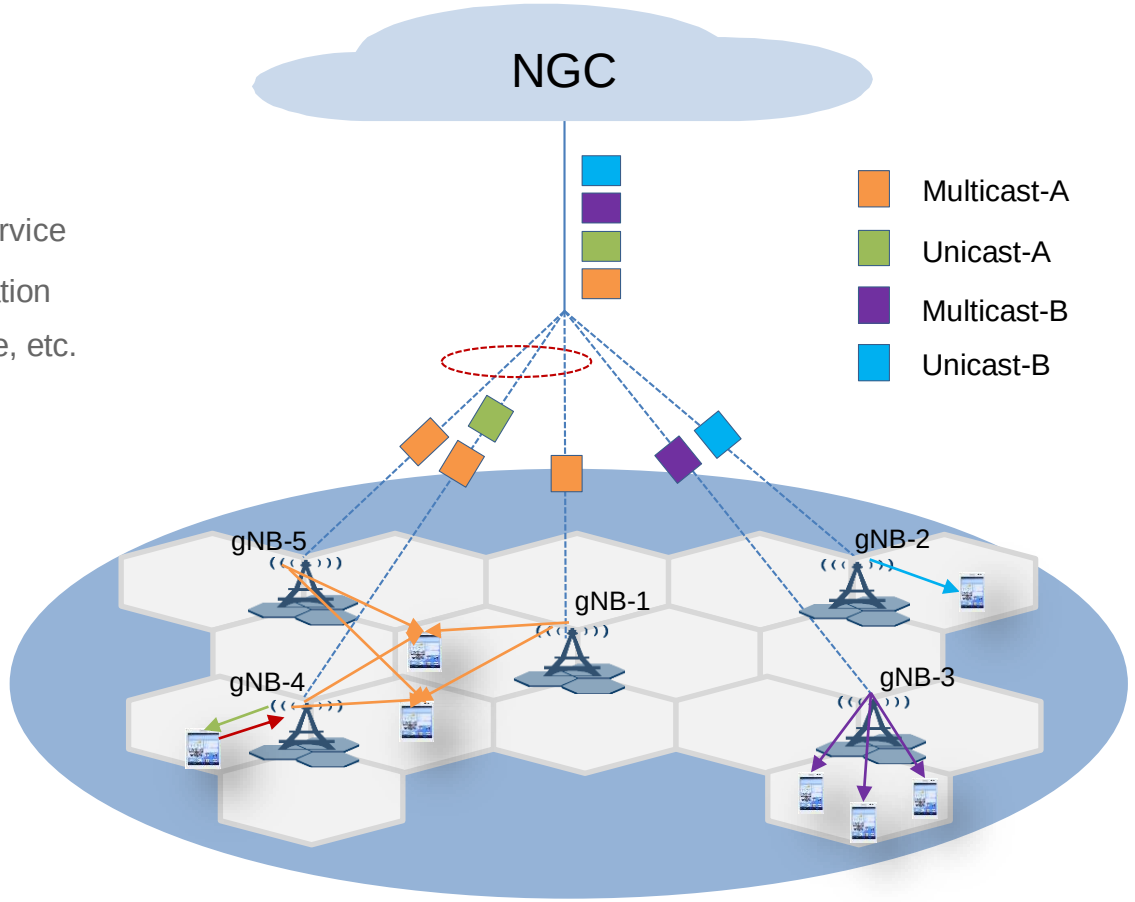
NR Broadcast/Multicast and Multi-Media 5G Services

Motivation: support cellular based mixed mode broadcast/multicast/unicast

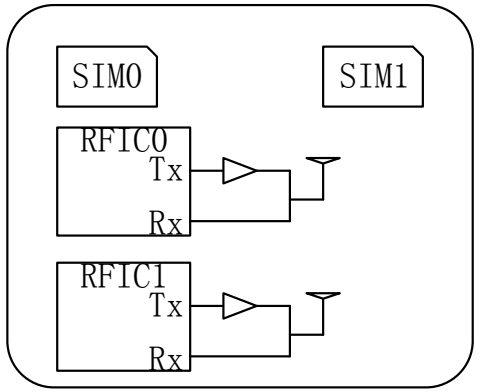
- **4G broadcast**: not scalable architecture; not flexible broadcast region; low efficiency RAN
- **Vertical use cases**: public safety, V2X, IIoT, PMSE, AR medical, etc.

Objectives for NR Rel-17 mixed mode multicasting

- **Flexible single/multi-cell broadcast region** adjustment based on UE location and service
  - Common design framework for single/multi-cell broadcast, e.g. unified configuration procedure and PHY channel design, e.g. PDCCH/PDSCH, BWP, frame structure, etc.
- **RAN architecture** enabling the flexible broadcast region
  - Study need for Multicast control function(MCF) and SYNC protocol
  - Consider both CU-DU localized and distributed gNB deployments
  - Scalable RAN architecture to minimize deployment complexity
  - Local breakout
- **Service continuity**
  - Flexible switching among single/multi-cell broadcast, and broadcast/unicast
- **QoS-guaranteed broadcast** on spectrum efficiency, latency and reliability
  - Mechanisms of HARQ/CSI/RLC feedback
  - Flexible to meet different QoS requirements for variety of broadcast services



Enhanced Support for Dual SIM UE



Service requirements：

- Receiving multiple paging simultaneously when all SIMs are in dual idle state
- Receiving paging of one SIM while another SIM is in connected state
- Having voice service of one SIM while having data service of anther SIM

MUSIM UE radio capability：

- LTE+LTE dual-SIM phone has already supported all the service requirements. No need to modality LTE specifications.
- In the near future, LTE+EN-DC dual-SIM, LTE+NR dual-SIM, NR+NR dual-SIM are the most promising MUSIM configurations
- For MUSIM UE, the minimum downlink RF chain configuration is two, and the minimum uplink RF chain configuration is two

Gap analysis：

- Downlink RF chain capability adaptation of one SIM, when receiving paging or RRM measurements are ongoing for anther SIM
- Uplink RF chain capability adaptation of one SIM, when another SIM is switched from idle state to connected state or vise versa.
- Power control/coordination between uplink RF chains for multi SIMs.

Objectives：

- ***Rel-17 study UE capability coordination and adaptation, power control, to address simultaneously transmission and receiving for multiple networks associated with multiple USIMs***

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Intelligent Networks (SON/MDT Enhancements)

- **Motivation**
  - SON/MDT is quite important for intelligent networks with OPEX (operating expense) reduction and performance improvement especially for multi-RAT scenarios.
  - Further enhancements on power saving/energy efficiency, possible new measurement quantities for MDT reporting for multi-RAT scenario based on the discussion in Rel-16
- **Proposals**
  - Network energy saving
    - TRX on/off with enhanced CSI measurement
    - Traffic profile aware scheduling enhancement to improve the sleep ratio and duration
    - Efficient activation/de-activation and coordination mechanism for multi-RAT scenario
  - SON/MDT enhancements for multi-RAT
    - Logged MDT for NSA cell
    - Failure cause report for SCG link interruption
    - Inter-RAT SON/MDT report
  - Flexible configuration information exchanging among network entities for the coexistence of NB-IoT/LTE and NR
  - Potential leftovers in Rel-16

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NR MIMO TDD Enhancement

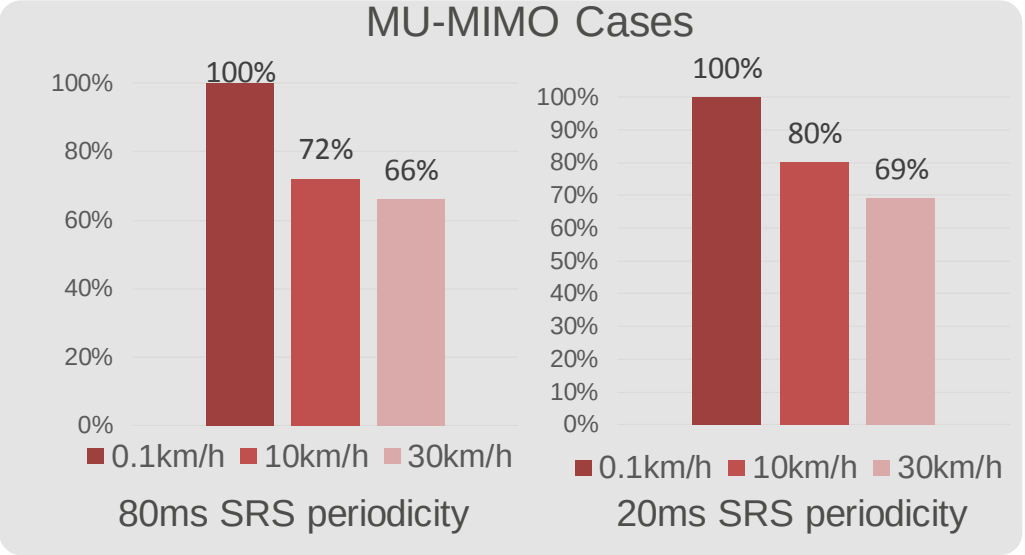
Sounding RS capacity extension

Motivations

- To train more Tx beams and/or obtain CSI from more UE panels for multi-panel UE, in single/multi-TRP scenario
- To support more frequent SRS transmission for moderate/high speed UE, due to reduced channel coherence time
- To support SRS transmission from more UE in a hot-spot area (with, e.g., 800 connected UE)

Potential solutions

- Increase the number of SRS base sequences, considering extremely low intra-cell interference and backward compatibility
- Specify a low-density reference signal for tracking time-variation information of channel and reduce SRS overhead



The results show SE loss compared with @0.1 km/h for MU-MIMO for 20ms and 5ms SRS periodicity

Advanced MU-MIMO receiver

- Residual MU interference exists for scenarios like:
  - UEs are spatially collocated, or
  - CSI is not accurate due to CSI aging or UE w/o antenna switching
- Receiver can help to further cancels MU interference
  - e.g., gNB indicates interference information to enable codeword level MU interference cancellation at UE side

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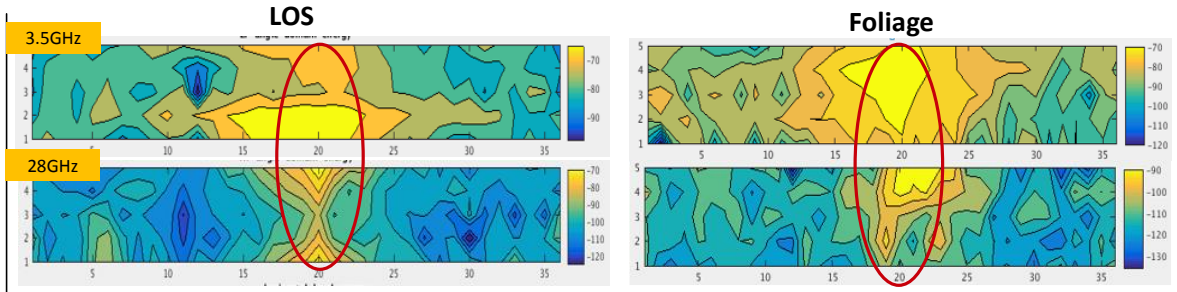
FR2 Enhancements

Overhead and latency reduction for beam management

- Multiplexing of SSB(s) and UE-specific PDSCH in some cases
- LF assisted HF beam management by exploiting spatial correlations
- Joint DL/UL or P2/P3 beam training via a single trigger

Overhead from scheduling restriction around SSB (120kHz SCS for PDSCH and SSB)

SSB periodicity (ms)	# of available DL symbols (DL:UL = 4:1)	# of symbols for 64 SSBs	Overhead
10	1120 * 0.8	256	28.57%
20	2240 * 0.8	256	14.29%



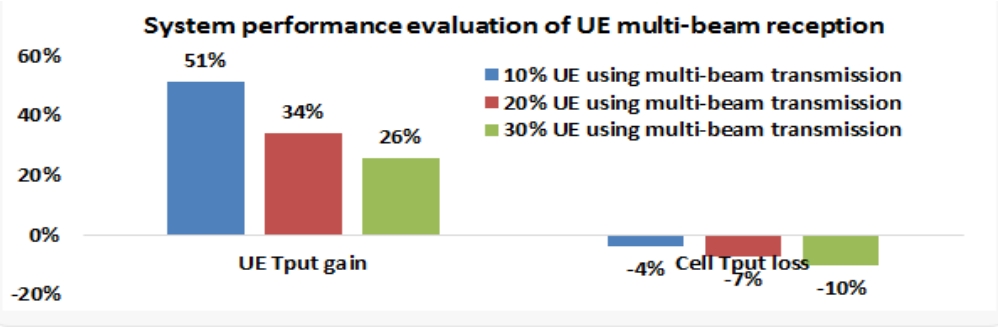
UE angular power profile between 3.5GHz and 28GHz
X/Y axis: Horizontal/Vertical beam index (10/10 Deg)

UE power saving specific to FR2

- UE power consumption is much higher than FR1 due to the frequent beam sweeping operation, crucial issue for hand-held devices
- Simplified beam management mechanism during UE DRX cycle, and maintain beam alignment between BS and UE with the minimum beam training/measurement activities.
- UE multi-panel simultaneous operation has to take the UE power saving into consideration

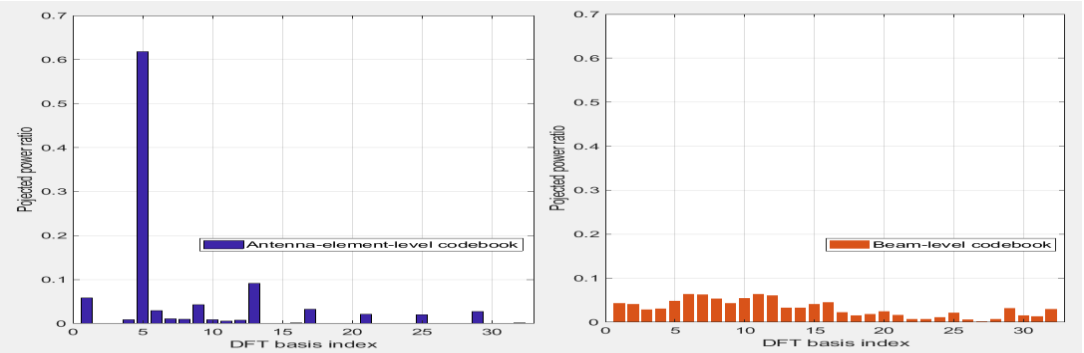
UE experience improvement in case of mobility/rotation

- NW assisted UE initiation of beam training
- Tx beam correlation assistance for UE smart beam selection avoiding overall beam set failure
- Simultaneous multi-panel reception for beam diversity



System capacity enhancement

- Precoding for MU interference mitigation has to rely on the PMI feedback, due to AIP RF architecture with unfavorable TX/RX reciprocity
- Rel-15/16 Type II codebook is not suitable especially for WTTx use case (application restriction, Low precision)



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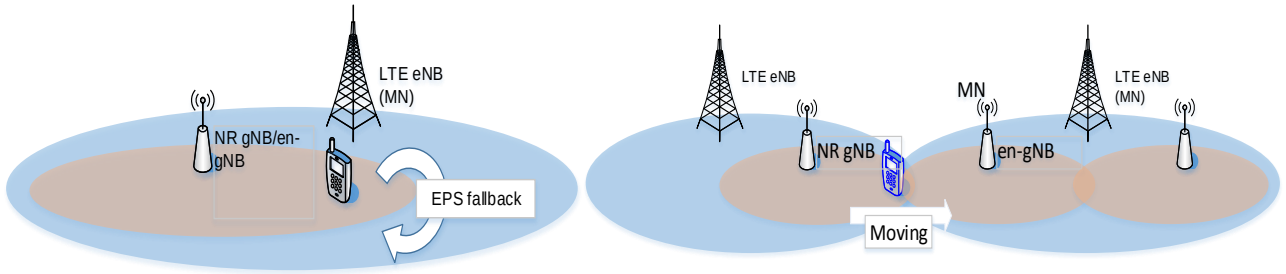
NR IAB Enhancement

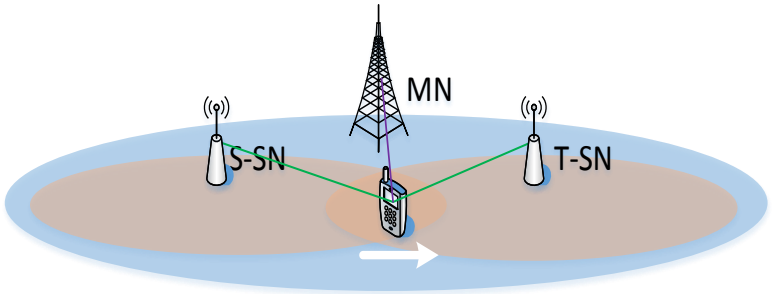
Rel-16 IAB only defines basic specification framework due to limited TU. Rel-17 IAB enhancements will provide advanced features for performance enhancements, which includes

- Inter-IAB CLI management to enable multi-hop topology
- Dynamic SDM/FDM based resource allocation between parent backhaul link and child link
- High order modulation on backhaul link i.e. 256QAM
- IAB inactive mode for energy saving
- Multiple connectivity enhancement e.g. support of packets duplication over backhaul link
- IAB operation in NGEN-DC and NE-DC mode
- LTE access over NR backhaul (if any standard impact identified)
- End to End ARQ to simplify the protocols and processing of IAB node

Mobility Enhancement for EN-DC



Scenario 1：Direct HO from NR SA to EN-DC



Scenario 2：0ms SN change

- **Motivation**
  - **Scenario 1:** In Rel-15, HO from NR SA to EN-DC (i.e. handover from NR to LTE + SN addition in one step) is not supported: target eNB can only perform SN addition after UE finishes HO, during SN addition procedure, UE can not use SN to boost data rate. EPS fallback is one example but we want to cover this in the case of 5GC only also.
  - **Scenario 2:** In case of EN-DC, SN change happens more than legacy HO, considering SN will carry most of UE data transmission, data interruption due to SN change has more impact on UE experience and therefore 0ms interruption should be considered for SN change.
  - **Scenario 3:** In Rel-16, 0ms intra-NR and intra-LTE HO will be achieved, but the mobility enhancements on HO between EN-DC and EN-DC should also be considered. In principle we could also look at other MR-DC options, with lower priority
- **Proposals**
  - Mobility enhancements for EN-DC
    - HO from NR SA to EN-DC in one step
    - 0ms SN change in case of EN-DC
    - 0ms EN-DC HO

Note: All the enhancement can apply to other DC options, e.g. NGEN-DC, NE-DC and NR-NR DC.

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NB-IoT Enhancements

- **Motivation**
  - **Total replacement of 2G M2M:** ensure CIoT eco-system is capable to carry all existing 2G M2M services as well as provide outstanding LPWA service experience.
    - Under same coverage (MCL), the average ping latency of GPRS is ~0.7s (minimum DRX cycle 0.47s) and the average ping latency of NB-IoT is ~1.4s (minimum DRX cycle 1.28s).
  - **New use cases:** demand from the market to support more IoT applications related to human experience (e.g. wearables including health/fitness/emergency IP based voice etc.) which require slightly higher peak data rate.
  - **IoT evolution within 5G NR:** CIoT has been commercialized around the world and is capable to connect to 5G CN (ongoing in Rel-16), further harmonizing the evolution of existing CIoT technology within NR is key to fully utilize both eco-systems to support from low-end to high-end IoT use cases.
- **Proposals**
  - Latency reduction for NB-IoT to be more competitive than GPRS in the same coverage
  - Increased peak data rate for NB-IoT to support more diverse IoT applications
  - More efficient support of mixed-service from network perspective by using different carriers, e.g., metering and latency sensitive applications access from different carriers.
  - Improved NB-IoT multiple carriers operation to support frequency hopping/diversity between two carriers.
  - IoT relaying to further extend the coverage to support very-deep deployment (also in SA Rel-17 scope).
  - New non-anchor carrier (e.g. reduce overhead, share between NB-IoT/LTE-M and NR, etc.).
  - Support for inter-RAT mobility between NB-IoT/LTE-M and NR
    - Including a study on embedding CIoT with smartphones to provide basic connectivity (e.g., for public safety including message, emergency alarm, etc.) outside of LTE/NR coverage and low power consumption mode

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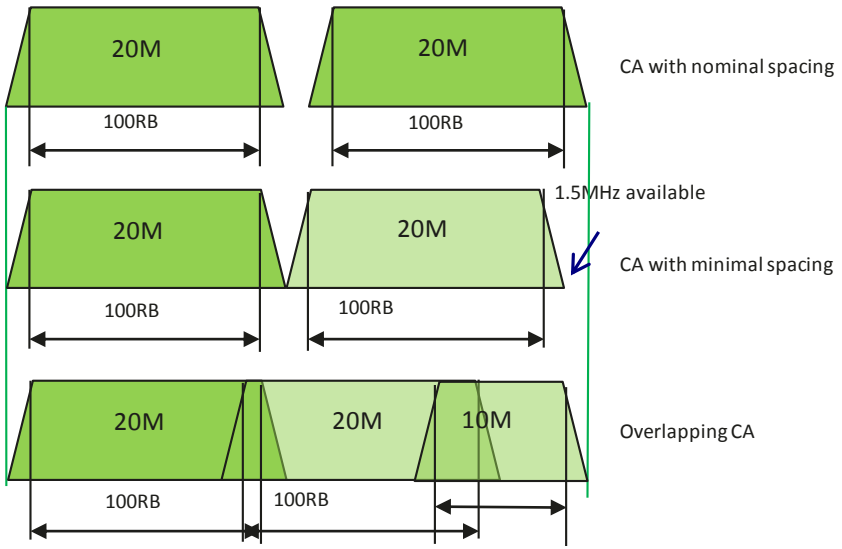
LTE eMBB Enhancement

- **Motivation**
  - LTE market status: penetration rate ≈2/3 in 2025, the dominant eMBB traffic would still be delivered by LTE in the next few years.
  - Due to the roll out of unlimited package service, the DOU (dataflow of usage, i.e., the average monthly mobile internet traffic per user) keeps growing quickly and it is essential for operators to provide LTE based capacity enhancements by leveraging the existing tons of sites.
  - eMBB enhancements for LTE could benefit the user experience in NSA as well.

- **Proposals:**
  - Enhancements on CSI measurement and reporting, e.g., high precision codebook [RAN1]
  - Specify RAN4 demodulation requirements to enable minimum spacing of more band combinations for intra-band contiguous CA contiguous CA [RAN4]
  - Overlapping CA operating bands and channel arrangement:
    - Notation of overlapping CA, add new CA configurations/bandwidth class, and update of channel spacing to allow overlapping CA



Thank you.

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