RWS-210436

3GPP TSG RAN Rel-18 workshop
Electronic Meeting, June 28 – July 2, 2021

Agenda Item: 4.3

NR uplink boosting

Huawei, HiSilicon

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Contents

- Motivation, Use Case and market outlook
- Capability and limitations from R15 ~ R17 standards
- Potential UL enhancement directions
- Summary

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Typical use cases of UL services for ToC and ToB

ToC：upgraded mobile services 10~30Mbps

2020 — 5G → **2025** — 5G Evolution

Video calls

OTT Video
480P/720P
0.8~1.5Mbps

HD Video
1K/2K
4~10Mbps

Broadcast

Online broadcast
and shopping
720P/1080P
1.5~4Mbps

HD broadcast
live video
2K/4K
10~25Mbps

eXtended Reality

Cloud gaming

Cloud VR

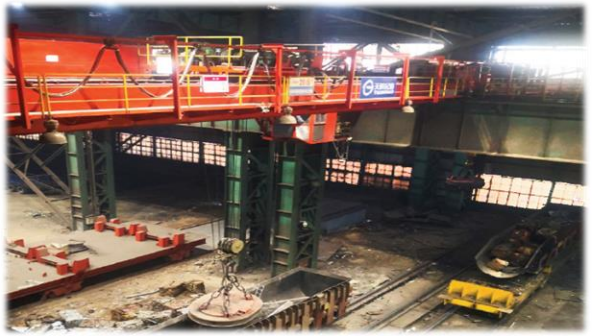
UL: low-latency transmission of ~ 1 Mbps

AR

UL: up to 30 Mbps

ToB：typical applications are UL heavy

Smart steel: sky machine monitoring and remote control



Smart coal mining

From in-person operation to remote control

Smart port

Digitalized factories

Monitoring, remote control & &auto drive

- **UL data rate: >30 Mbps** per crane
- Machine vision
- **UL data rate ~100Mbps or higher** for machine vision at factory
- 18ms average and 30ms maximum latency

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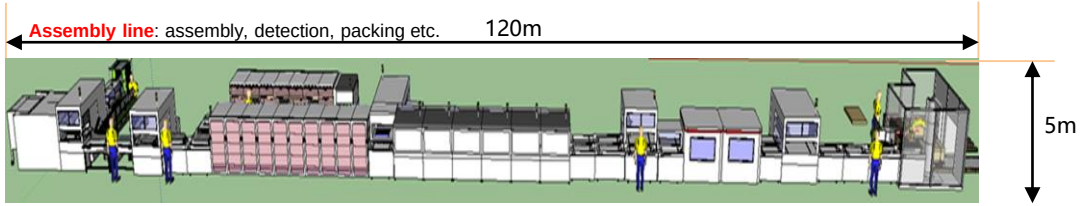
Source：《Values of 5G Uplink Capabilities in Industry Digitalization》in Chinese, CMCC, Huawei, October, 2020

Example of ToB deployment/application scenario

Example： smart assembly line @Dongguan, China



16 detection video points for each assembly line, and 8 lines in the area

Network deployment zone	**8 Assembly lines**
UE density	**16 UEs / assembly line**
UE with data in buffer	**60%**
Uplink throughput required	**80Mbps/UE, ~6Gbps required at the zone**

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Capability and limitations from R15 ~ R17 standards

① Frequency domain

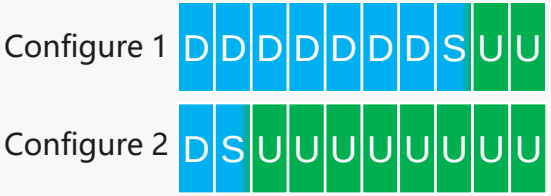
SUL band combination（two carriers）
UL TX switching between carriers

CA band combination：2 bands;
UL TX switching between carriers

- Uplink CA: limied number of UL carriers due to UE RF TX capability
- **UL TX switching: only between two bands and only for 2Tx UE, quite many scenarios not addressed**

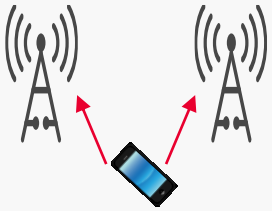
② Time domain

- Flexible UL/DL configuration

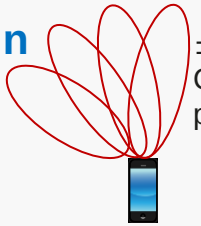


- The DL/UL symbol ratio can be configured flexibly
- More UL slots provide more UL capacity
- Macro base station using DL heavy slot ratio for DL heavy traffic
- **Local area potentially have UL heavy traffic (e.g. UL video)**
  - **Interference from Macro to small cell and UE to UE is not sufficiently well addressed up to Rel-17**

③ Spatial domain



Joint RX on multiple TRP,
transparent to UE

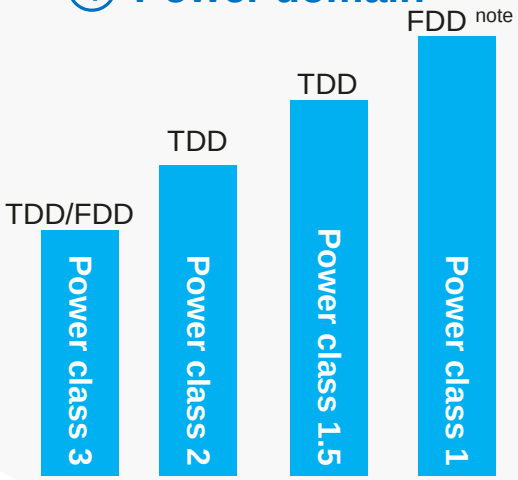


±1, ±j
Coarse
pre-coder

Uplink precoding
Wideband precoding:
one codebook for all RB/UE

- Smaller number of Uplink TX antennas 2 or 4 (high end UE)
- **Precoding: wideband precoding, ± 1& ±j coarse pre-coder element**
- **Up to 12 orthogonal UL-MIMO layers:** DMRS interference for non-orthogonal DMRS port

④ Power domain



- Power class 3: 23dBm
- Power class 2: 26dBm
- Power class 1.5: 29dBm

With duty cycle for TDD

- Power class 1: 31dBm (CPE)
- Duty cycle is a UE capability to support higher power (50%~100%)
- **Handset SAR limits the maximum power**

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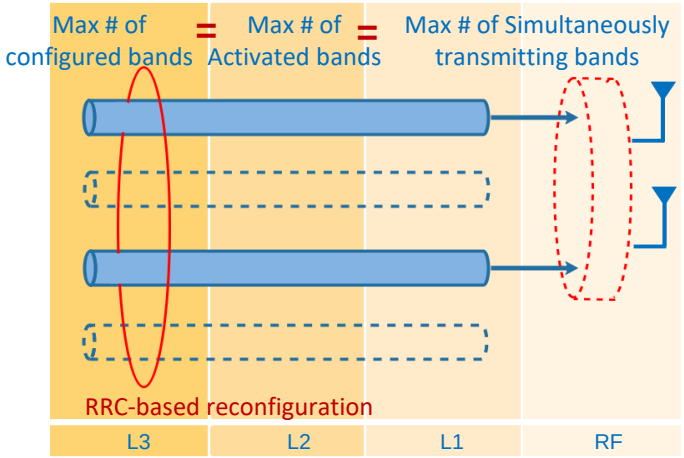
note: The FCC Public Safety and Homeland Security Bureau mandates LTE technology for the 700 MHz Public Safety band (3GPP Band 14)

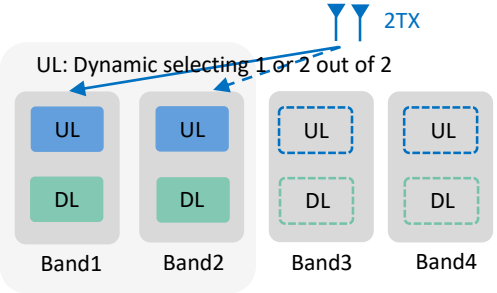
Frequency domain: Flexible Spectrum Access

Legacy mechanisms



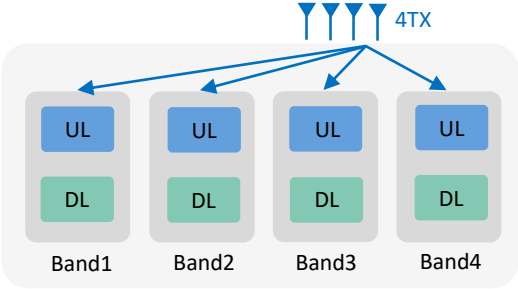
- **Coupled** UE capability of config /activation/simultaneous transmission for CA/DC.
- For 2TX UE, Tx switching between 2 configured bands, change bands by RRC reconfiguration.

R17



2 bands access Low UE cost

4 BANDS UL CA

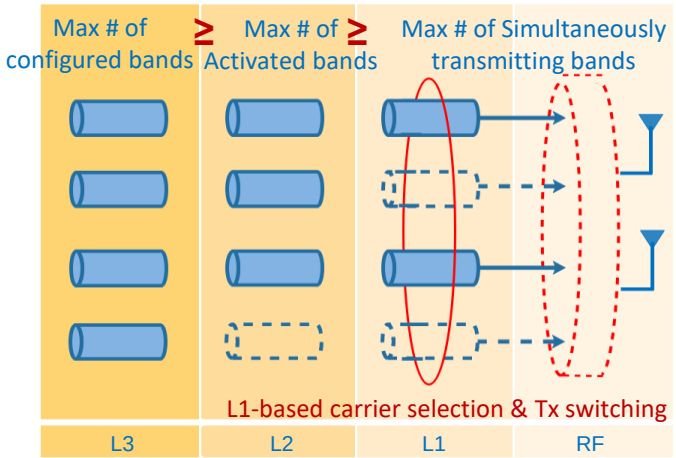


4 bands access High UE cost

Challenges

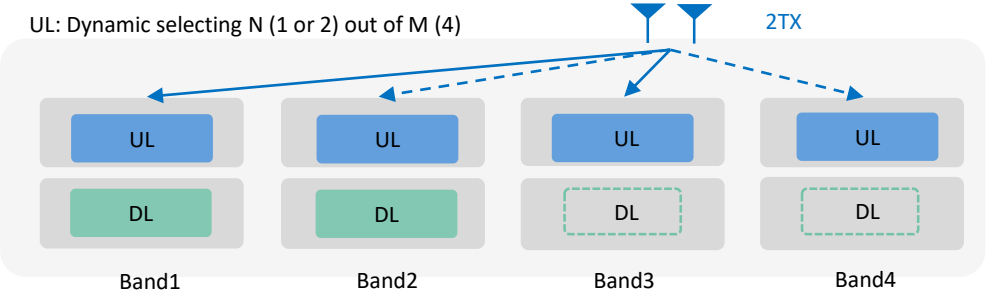
- R17 solution cannot fully utilize all spectrum resources.
- 4 bands UL CA solution has difficulties in implementation.
  - Power consumption, heat issue, complexity, spurious emissions, etc.
  - Some Tx is unused due to power limitation or TDD DL slot restriction.

Flexible spectrum access



- **Decoupled** UE capability of configuration /activation/simultaneous transmission for CA/DC.
- For mTx (m>=2) UE, dynamic carrier selection & Tx switching between n (n>=2) configured bands.

FSA (2Tx UE as example)



4 bands access Low UE cost

Benefits

Fast carrier & Tx switching between n (n>2) bands brings more time and frequency resources, TTI-level load balancing and larger frequency selectivity, which leads to :

- Higher UL data rate.
- Higher UL capacity for latency-bounded traffic.
- Higher system spectrum utilization.

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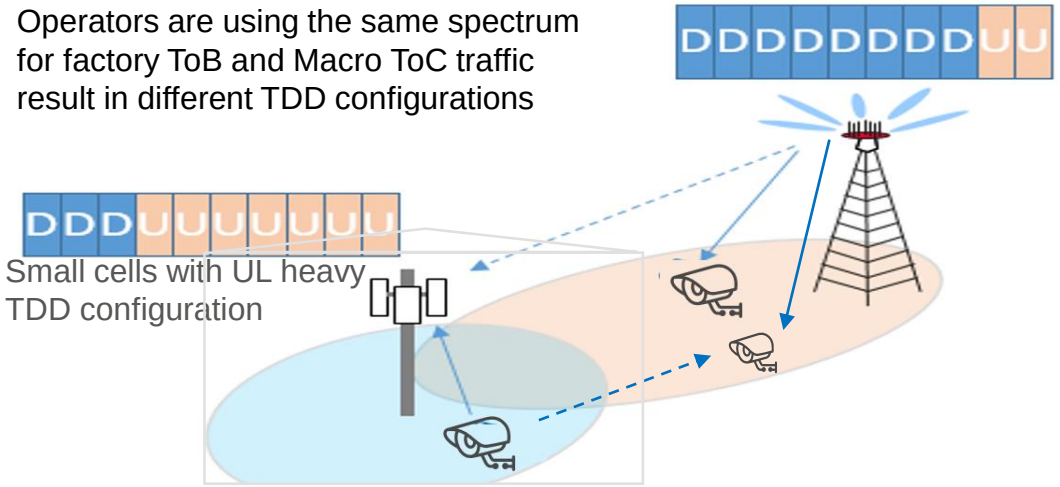
Time domain: BS-BS/UE-UE CLI enhancement for UL dominant TDD in Rel-18

BS-BS interference scenario in FR1

Macro BS with DL heavy TDD configuration

Operators are using the same spectrum for factory ToB and Macro ToC traffic result in different TDD configurations



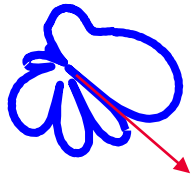
BS-BS interference needs to be cancelled in FR1

Distance(macro BS to small cell)	50m	100m	200m
Macro TX power（dBm）	50	50	50
BS TX antenna array gain (dB)	20	20	20
Penetration & shadow fading (dB)	35.5	35.5	35.5
Pathloss outdoor （dB）	81.1	86.8	93.0
Pathloss indoor （dB）	2.5	2.5	2.5
Received interference（dBm）	-49.1	-54.8	-61.0
Noise power (dBm) with 7dB noise figure	-87	-87	-87
Interference to noise ratio（dB）	37.9	32.2	26.0

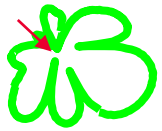
TX/RX joint BS-BS CLI management

Joint DBF @TX&RX

Beamforming @Macro



Micro: IRC Rx @Small cell



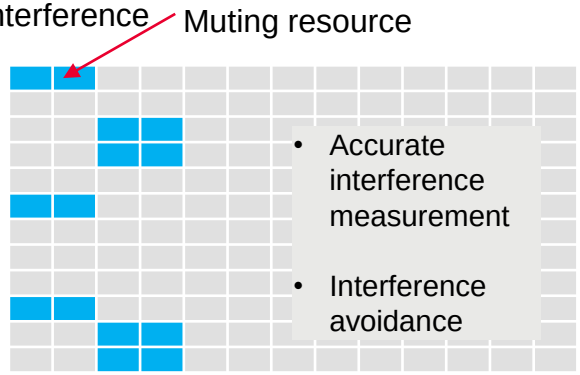
$$\hat{s} = H^H(HH^H + R_{uu} + \mathrm{I})^{-1}Y$$

Different BS-BS CLI signal/characteristics

Interference channel/signal	Interference characteristics
Downlink broadcast interference: SSB, SIB1, broadcast PDCCH, cell specific CSI-RS, TRS etc.	Beamforming of the signal or channel are stable and constant for each transmission, the interference may be measured once and used for several times.
Unicast PDSCH/DMRS	The interference is changing due to the precoding and scheduling changing slot by slot
UE dedicated CSI-RS	Sparse resource in frequency and time domain.

Small cell uplink RE muting: for BS-BS dynamic interference measurement/avoidance resource

- Flexible UL muting resource to match the interference
  - instant accurate DL interference measurement, e.g. PDSCH interference
  - semi-static DL interference measurement, e.g. SSB
  - avoid sparse DL signal interference, e.g. CSI-RS



Need Macro to small cell channel estimation

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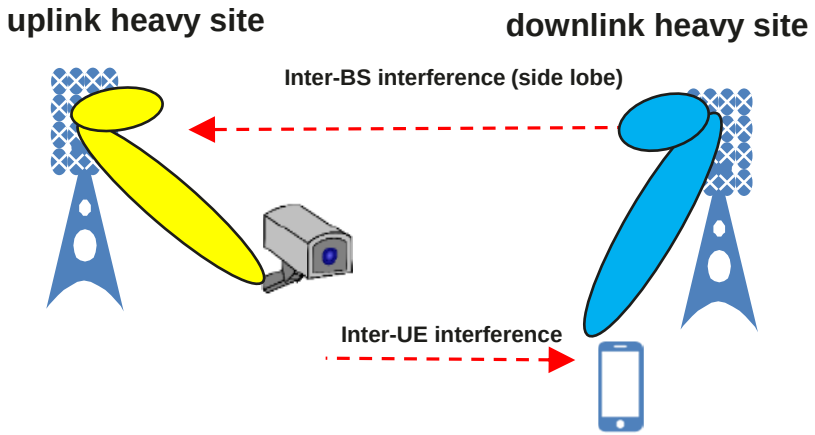
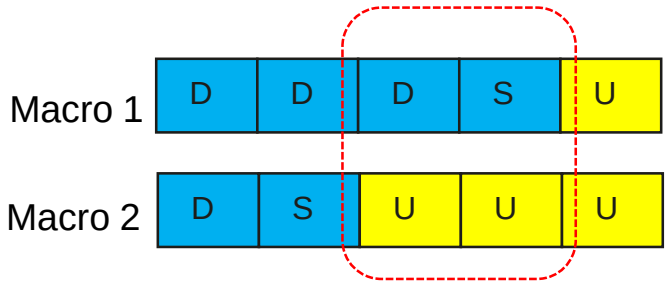
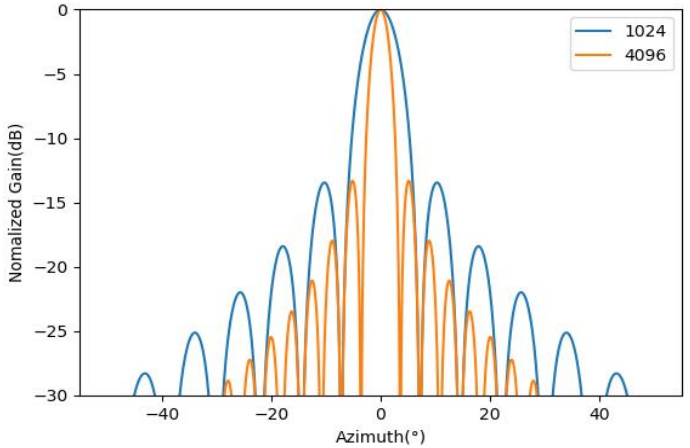
Time domain: BS-BS/UE-UE CLI enhancement for UL dominant TDD in Rel-18

Scenario: Macro – Macro CLI in FR2

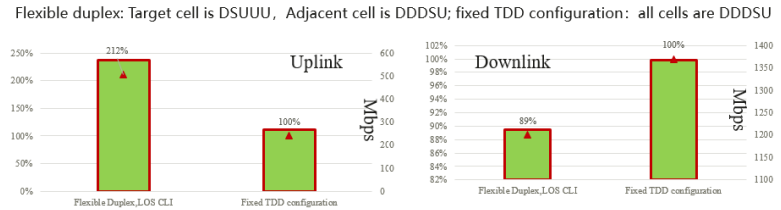




Flexible configuration for large uplink and large downlink traffic



Larger array: 1024 to 4096, narrower beam, better side lobe suppression to suppress CLI



Initial results show Macro flexible duplex in FR2 is feasible and provides uplink gains

- Large number of elements (4096) helps to reduce the BS-BS CLI, and increase the freedom of beam coordination
- Fixed camera may have higher transmit power: UE-UE CLI measurement enhancement are useful for lower overhead and accurate measurement.

- BS-BS cross link interference management and UE-UE CLI management enhancement should be studied and specified in R18 for both FR1 and FR2:
  - e.g. defining specific BS-BS interference measurement resources, : UL muting resource for BS-BS CLI measurement,
  - e.g. enhanced CLI beam measurement and coordination,
  - e.g. enhanced UE-UE measurement: L1 based UE-UE CLI management; optimized UE-UE CLI measurement configuration

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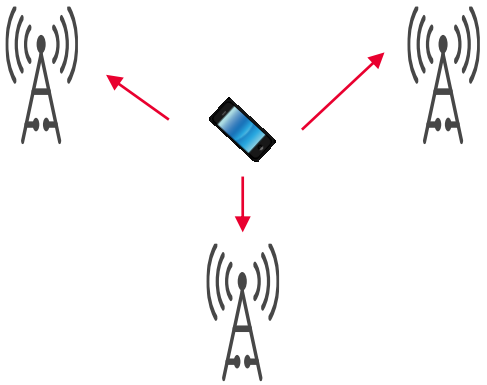
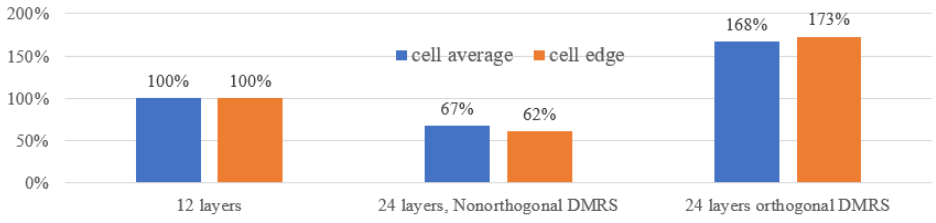
Spatial domain: Uplink enhancements – uplink MIMO



- Uplink MIMO capability is weaker than the DL
- Multiple TRP UL joint processing can improve the uplink performance significantly in a factory or in Macro/Micro cells

DMRS enhancements

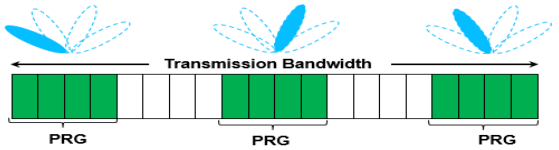
- For high UE density with heavy uplink traffic
- Larger number of uplink orthogonal DMRS port
  - e.g. 16 or 24 ports



- initial simulation results for enhanced orthogonal DMRS in the IIOT scenario mentioned in section 1

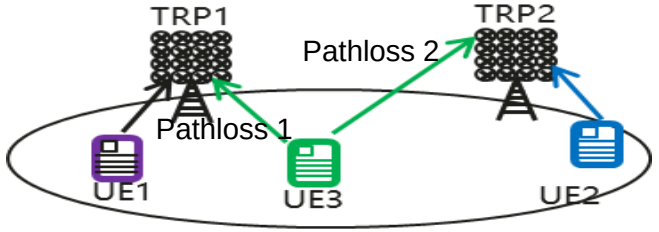
UL precoding enhancement

- Uplink sub-band precoding,
- High-resolution codebooks
- More antennas (4T, 8T).



Enhanced power control by multi-TRP

- UL Power control by jointly considering multiple TRPs.



Power control considering both TRPs

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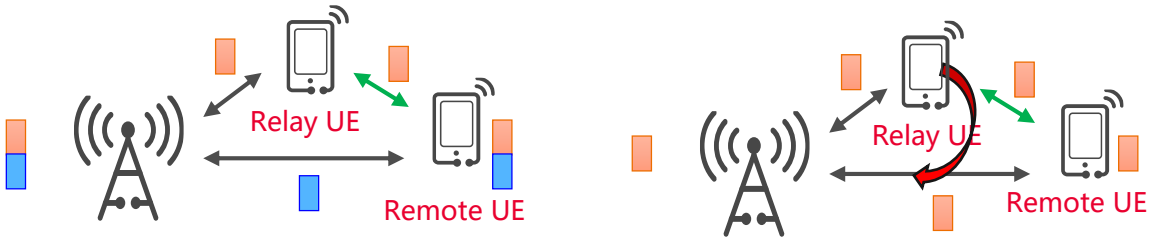
Power/diversity domain

Multi-path connectivity UE



- Data split (duplicate) among multiple path including direct and indirect path
- Fast path switch based on DAPS between direct and indirect path for intra-gNB
- Aggregating more resource (power, antennas, frequency to boost the UL experiences (throughput/latency/service continuity)

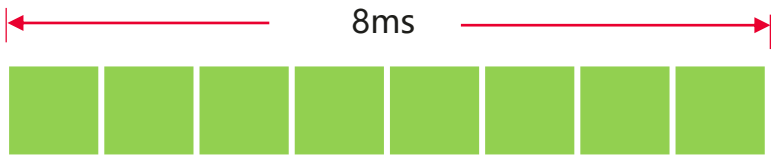
Most promising use cases:

- ToC and ToB traffic
- Enhanced public safety

FDD high power UE

For FDD band, the maximum average power can be increased to boost the UL coverage

- Baseline：23dBm



- FDD high power UE：26dBm @ 50% time

- FDD high power UE：26dBm @ >50% time

- Different FDD high power UE capability on duty cycle.

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Summary: proposals for NR uplink boosting in R18

- ***Frequency domain:***
  - ***Proposal 1****: Specify the mechanisms to allow a UE (e.g., 2TX or 3TX UE) to be configured with more UL bands than its simultaneous transmission capability and specify mechanism for dynamic carrier selection as well as TX switching between n (n>=2) configured bands applicable to SUL, CA and DC.*
- ***Time domain***
  - ***Proposal 2****: BS-BS cross link interference management and UE-UE CLI management enhancement should be studied and specified in R18 for both FR1 and FR2: defining specific BS-BS interference measurement resources, e.g. UL muting resource for BS-BS CLI measurement, enhanced CLI beam measurement and coordination, L1 based UE-UE CLI management.*
- ***Space domain***
  - ***Proposal 3****: UL MIMO transmission enhancement is considered and specified, e.g. enhanced UL precoding transmission including sub-band precoding and higher resolution codebooks for larger (4, 6, 8) number of UE TX, increased maximum number of orthogonal DMRS ports (up to 16 or 24) and UL power control enhancement to better support more UL MIMO layers and UL mTRP reception.*
- ***Power domain***
  - ***Proposal 4****: Study and specify multi-path connection, multi-path transmission and fast path switch in Rel-18 for sidelink based relay*
  - ***Proposal 5****: specify FDD higher power UE*

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