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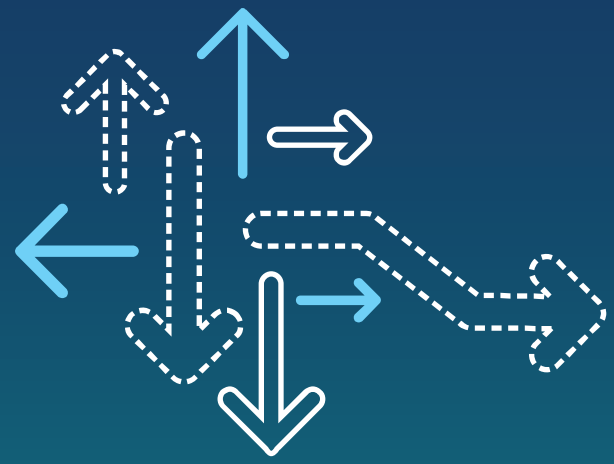

Views on NR UL Coverage

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Introduction

- In this contribution we discuss views on the following topics
  - Possible sources of DL/UL link budget imbalance
    - whether any of the sources depend on operating frequency
  - UL sharing

Background: Comparison of operating frequencies

Propagation loss

- In the free-space propagation loss equation, there is a factor f^2 → at twice the frequency, 6dB greater loss
- However, the frequency dependency in the equation is due to assuming the antenna size is proportional to lambda/2
  - Assuming the same antenna size, there is no higher free space propagation loss at higher frequencies
  - May require more antennas in higher frequency but within the same area → FD-MIMO
- In the case of non-free-space propagation, higher frequencies do exhibit higher loss due to penetration loss, scattering, etc. but this is not related to the f^2 factor

Background: Comparison of operating frequencies

DL/UL imbalance due to frequency

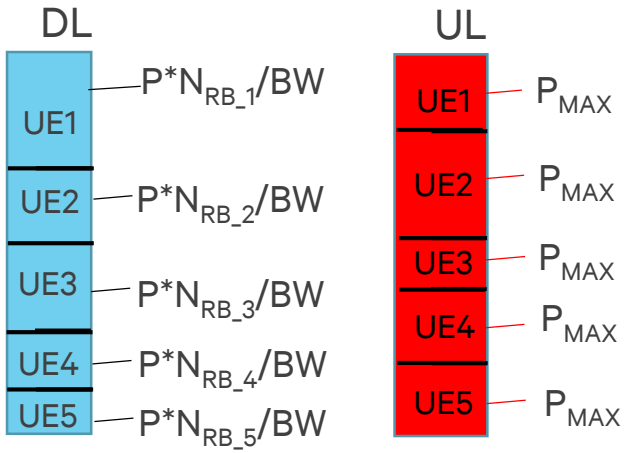
- In any case, propagation loss differences due to frequency differences impact the DL and UL the same way
  - Therefore there is no frequency dependent link budget imbalance due to propagation loss differences

- There are some second order differences, e.g. lower noise figure in eNB Rx vs. UE Rx; however, these are also not frequency dependent in the first order

Background: Power difference

Higher DL power compared to UL

- Typically there is a large difference (~ 20dB) between Tx power in DL an UL
- Why isn't there a corresponding large link budget imbalance between DL and UL?
  - DL power is divided among many FDM'd UEs, while the UL power is 'pooled'



Background: Power difference

What may have changed

- If the multiplexing order is reduced, e.g. because of analog beamforming in mmWave
  - The power division / pooling effect (mentioned in previous slide) between DL and UL is also reduced
  - → DL/UL Tx power difference may result in DL/UL link budget imbalance
  - This factor is not related to frequency differences

- If the UL power has to be reduced, e.g. because of RF exposure limits (MPE) in mmWave
  - → UL Tx power reduction may result in DL/UL link budget imbalance
  - This factor is not related to frequency differences

Impact of channel estimation performance

Beamforming

- As it was mentioned earlier, we need larger number of antenna elements at higher frequency within the same area as the antenna element size gets smaller
- To combine the signals received on multiple antenna elements, we need an estimated set of complex combining gains

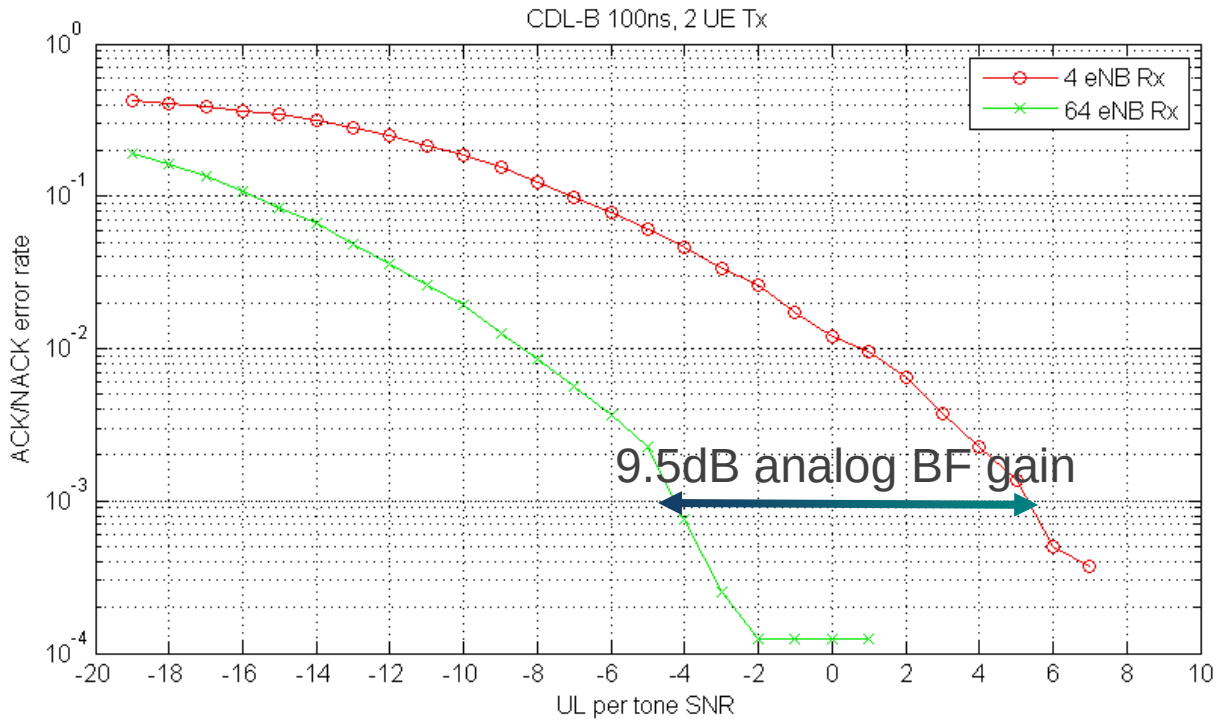
- There have been arguments that due to the smaller UL power, the estimation quality of the UL Rx combining gain (at the gNB) is significantly lower than the DL Rx combining gain (at the UE)

- However, we don't believe these arguments are correct due to the following
  - The same beamsweep/beamselection algorithm used for DL control can be used for UL Rx beamsteering as well
  - In the case of analog beamforming, the combining gain is not estimated at the individual antenna element level

Impact of channel estimation performance

Simulation results

- Short PUCCH
  - Component carrier BW: 100 MHz
  - Waveform
    - OFDM (FDM RS with ACK)
    - 30 kHz tone spacing
  - # of PUCCH symbols: 1 symbol (~35us)
  - PUCCH BW: 1 RB, 360kHz
  - Payload size: 1 bit ACK, 50% RS overhead
- Number of antennas:
  - UE Tx: 2 antennas
  - eNB Rx: 2 ports
    - 2 elements per port for 4 eNB Rx
    - 32 elements per port for 64 eNB Rx



UL sharing introduction

Conflicting input regarding use cases

- Seven different use cases mentioned
  1. DL/UL link budget imbalance mitigation
     - Discussed in previous slides (also in RP-170758), not seen an issue
  2. TDD link budget limit due to traffic imbalance
  3. TDD spectrum utilization optimization
  4. TDD latency mitigation
     - NR should have tools already (e.g. self-contained subframe) to address this
  5. NSA without simultaneous UL transmission
     - Stated goal is to avoid power sharing and/or intermod problems
  6. Band packages
     - Doesn't seem to reduce number of 'band definitions'
  7. Make use of underutilized FDD UL spectrum in an existing band

#2 TDD link budget limit due to traffic imbalance

Has been a known problem for TDD

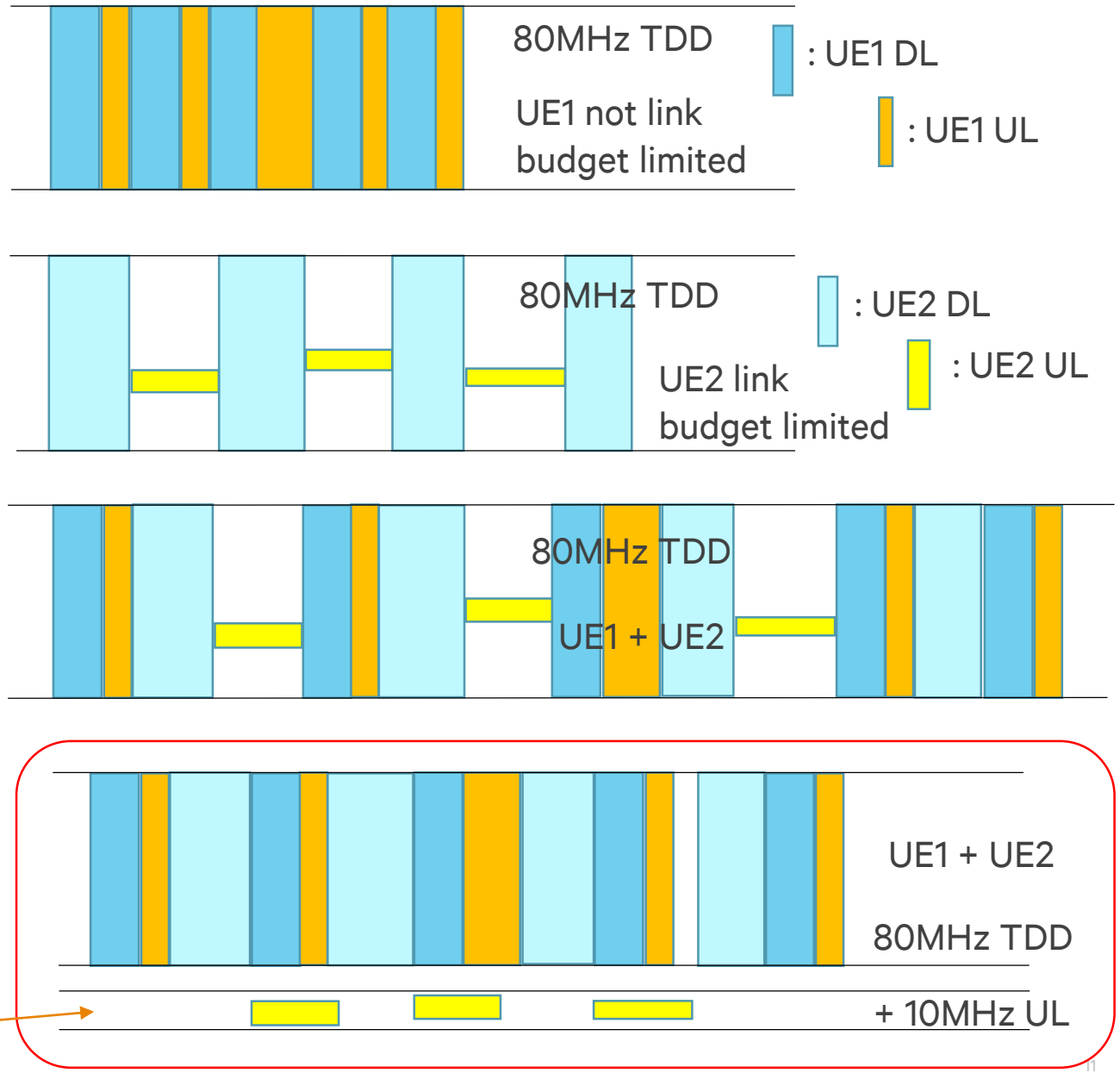
- The DL/UL time division ratio setting should satisfy conflicting requirements:
  - A) DL/UL time ratio should follow DL/UL traffic ratio,
    - → e.g. DL : UL = 10 : 1
  - B) DL/UL time ratio should provide for acceptable data rate for cell edge UEs
    - → e.g. DL : UL = 1 : 2

- Usually, the intent is to set the DL/UL ratio according to A), which puts pressure on the UL link budget
  - → The use of a Supplemental UL may alleviate this problem
  - This factor is not related to frequency differences

#3 TDD spectrum utilization

Will become an increasing problem for wideband TDD systems

- Related to the TDD link budget issue mentioned in previous slide
- Even if we can add sufficient number of UL slots for link budget limited UEs, these resources will be poorly utilized
  - Assuming limited UL multiplexing capability, e.g. due to beamforming
- Can use Supplemental UL
- Supplemental UL use is not related to frequency differences



#4 TDD latency mitigation

Doesn’t seem a sufficient motivation

- In TDD, the latency of one link direction is impacted by the availability of the link in the opposite direction for HARQ feedback
  - This factor is not related to frequency differences
  - LTE FDD-TDD CA with FDD PCell has always been seen very beneficial in latency reduction
- However, with self-contained TDD subframes, the problem can be mitigated in NR
- There is still a remaining issue in some limited cases
  - Where the TDD band has to coexist with LTE in an adjacent channel
  - Where DL/UL slot direction is governed by regulation to follow some LTE pattern

#5 NSA without simultaneous UL transmission

Doesn’t seem a sufficient motivation

- NSA implies two UL channels, one for LTE, one for NR
- There are some concerns regarding intermodulation associated with two ULs
  - However, if the two ULs are in different bands, separate PAs are used, so intermodulation should be a lesser concern
    - Even though intermod can be generated elsewhere, e.g. LNA
  - Moving the two UL to the same carrier in an FDM manner arguably make things worse
- Possible solutions to intermodulation issues
  - A) MAC-level aggregation
  - B) Scheduler-based TDM-ing on two different frequencies
- The need for avoiding simultaneous UL is not related to frequency differences

#6 Band packages

Have been proposed for NR band definition

- Taking CA as a model, where a particular CA configuration is selected from a number of band combinations available
- Follow a similar approach but without CA
  - E.g. have a set of DL-only bands (some could be DL part of FDD spectrum) and a set of UL-only bands (some could be UL part of FDD spectrum)
  - An FDD operating configuration can be assembled with pairing one DL channel with one UL channel selected from all available bands

- Looks nice on paper but in reality, each possible channel combination needs to be evaluated for feasibility and tested, so the amount work is not really reduced

#7 Recycling excess capacity

FDD traffic imbalance

- The claim is that in FDD LTE, there is excess UL spectrum due to traffic imbalance
  - Motivating UL sharing between LTE and NR
  - The same argument was used to motivate flexible duplex
  - This factor is not related to frequency differences

- The excess capacity could be also recycled with BW partitioning, without UL sharing
  - Assume the operator has 20MHz LTE, in which the UL is underutilized
  - Convert the 20MHz to 10MHz+10MHz DL CA (i.e. 10MHz FDD PCell aggregated with 10MHz DL SCell), and reuse the remaining 10MHz UL for NR

Conclusion

Link budget imbalance

- There are many reasons link budget imbalance between DL and UL may occur
  - Needs careful consideration which reason are relevant or irrelevant to NR use cases
  - Link budget imbalance is fundamentally not caused by going to higher frequencies

- Link budget imbalance may occur in mmWave due to other reasons
  - More frequent TDM-ing of UEs
  - RF exposure limit (MPE)

Conclusion

UL sharing

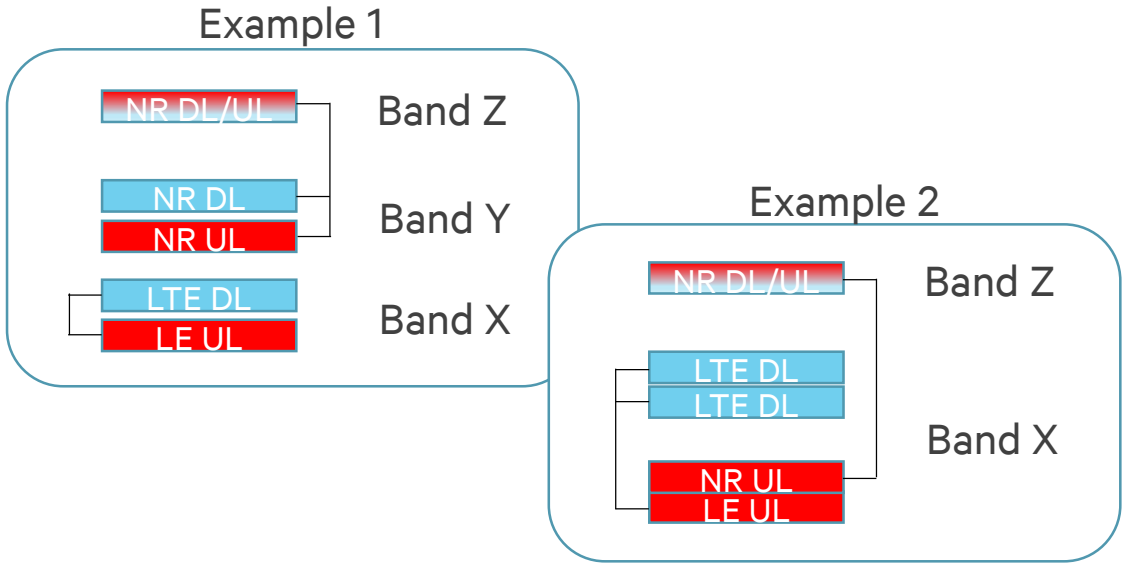
- Benefits are seen of Supplemental UL
  - Can alleviate some of the limitations of TDD
  - Reasons unrelated to frequency differences
- However, Supplemental UL doesn't need to be coupled with UL sharing

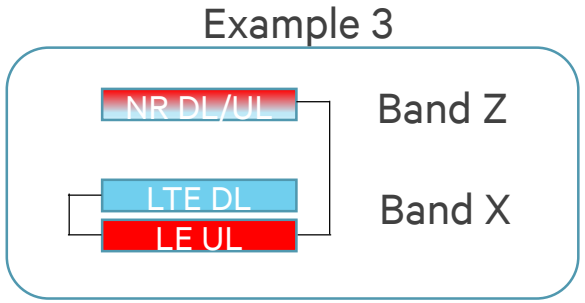
- In order to achieve RB alignment in LTE-NR UL sharing, it has been proposed to use 100 kHz NR channel raster in the applicable bands
  - → 100 kHz NR channel raster would prevent NR intraband contiguous CA without guard band in the same bands

Conclusion

Prioritize cases that do not require new extensive specification work; **minimize UL sharing work**

- For NSA
  - First priority: With multiple UL (with or without TDM)
    - Example 1:
      - LTE low band FDD (Band X)
      - NR low band FDD (Band Y) + high band TDD (Band Z)
    - Example 2:
      - LTE low band FDD intra-band DL CA (Band X)
      - NR low band UL-only (Band X) + high band TDD (Band Z)
  - Second priority: Without multiple UL (MAC-level aggregation)
    - Example 3:
      - LTE low band FDD (Band X)
      - NR high band TDD (Band Z), NR UL control in Band X in LTE format

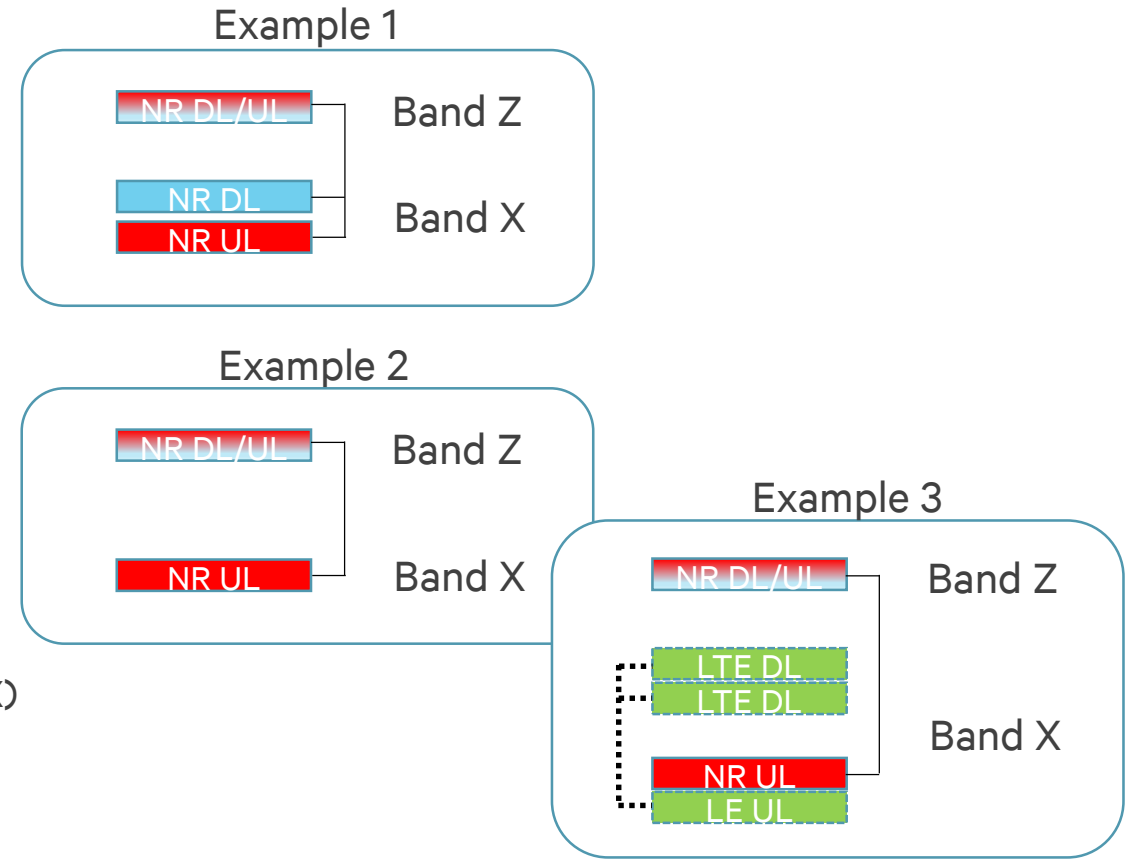




Conclusion

Prioritize cases that do not require new extensive specification work; **minimize UL sharing work**

- For SA
  - First priority: Use inter-band CA
    - Example 1:
      - NR low band FDD (Band X)
      - NR high band TDD (Band Z)
  - Second priority: Supplemental UL
    - Example 2:
      - NR low band UL (Band X)
      - NR high band TDD (Band Z)
    - Example 3:
      - For other UEs: LTE low band FDD intra-band DL CA (Band X)
      - NR low band UL-only (Band X) + high band TDD (Band Z)



Thank you

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