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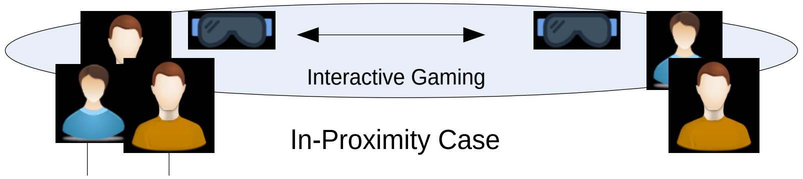
Release 18 Sidelink Evolution

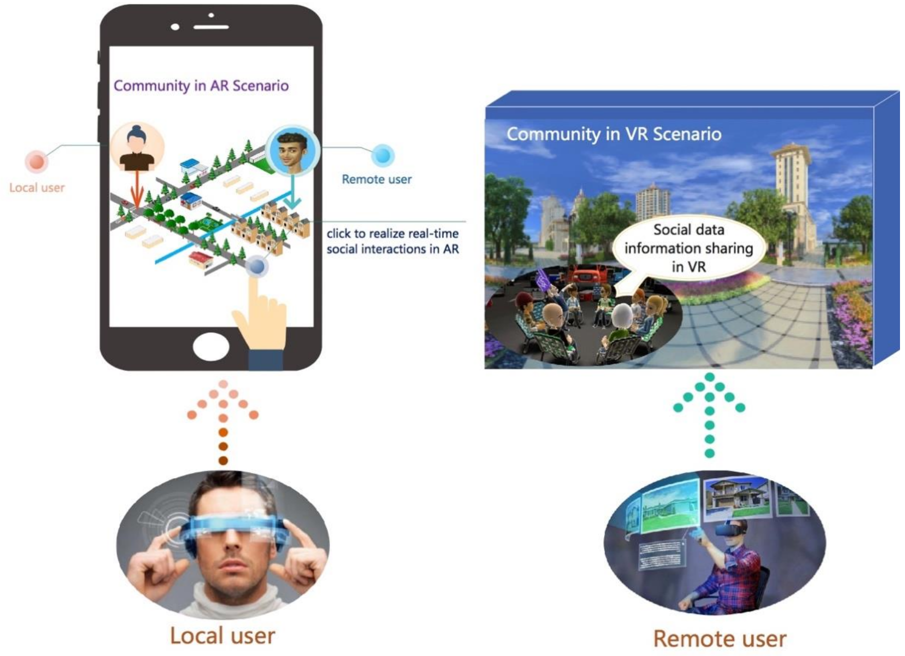
Sidelink over Unlicensed Spectrum

Use case: eMBB

- eMBB use case optimization is the key to our designs in many fronts
- For UE to talk to UE directly, without tunneling data through gNB
  - Especially for UEs not belonging to the same operators
  - Eg. Phone to XR headset for rendering, phone to phone gaming (peer 2 peer) for people in the same room, phone to wearable
- Benefits of SL-U:
  - Traffic offloading: No need to use Uu spectrum, esp when Uu is over licensed band
  - Air interface efficiency: No need to have two hops for the data transmission



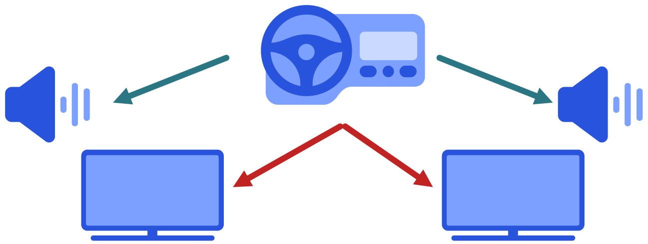
Interactive Service in TR22.842



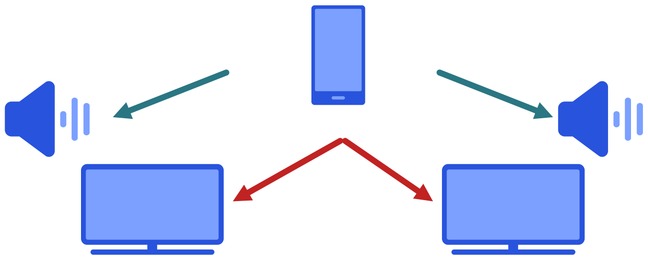
IoE based social networking in TR22.842

Use case: Wireless In-vehicle Networks

- Sidelink can be used for in-vehicle communications:
  - Video to displays, media from portable devices, audio to speakers, …
- This use case shares requirements with the eMBB use case:
  - Focus on high throughput applications.
  - Efficient channel access.
- Benefits:
  - Scalable solution for a spectrum of device complexity and power.
  - Integration with other NR technologies.



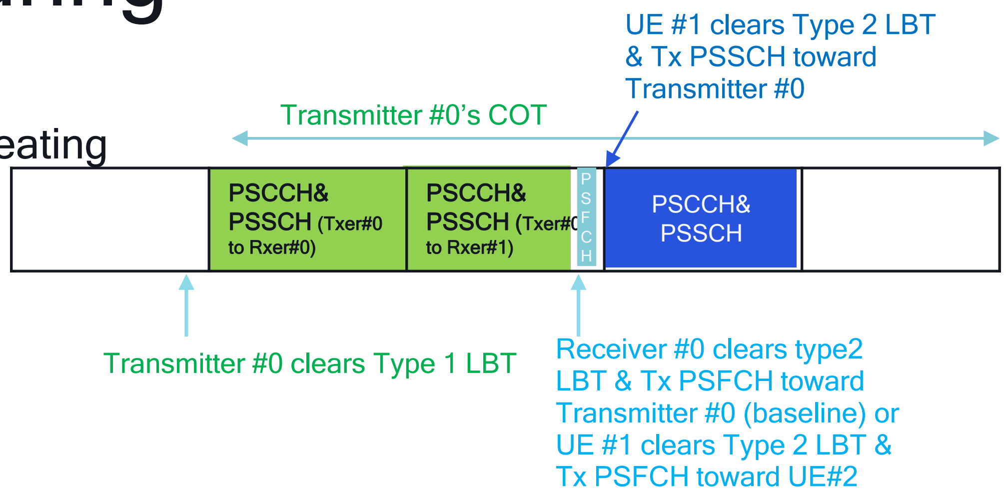
Transmission from car to its displays and speakers



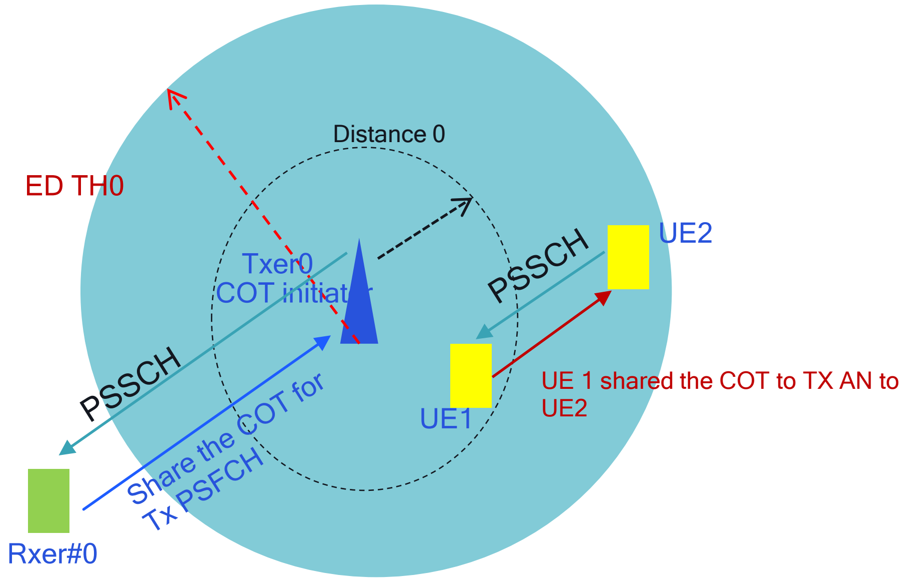
Transmission from mobile device to car’s displays and speakers

Channel Access: UE to UE COT sharing

- Support UE to UE COT sharing
  - At least support the COT sharing for the reverse link to COT initiator by treating it as gNB-to-UE or UE-to-gNB COT sharing in Uu
  - Help the starved SL node with COT sharing so it could use Type 2 LBT



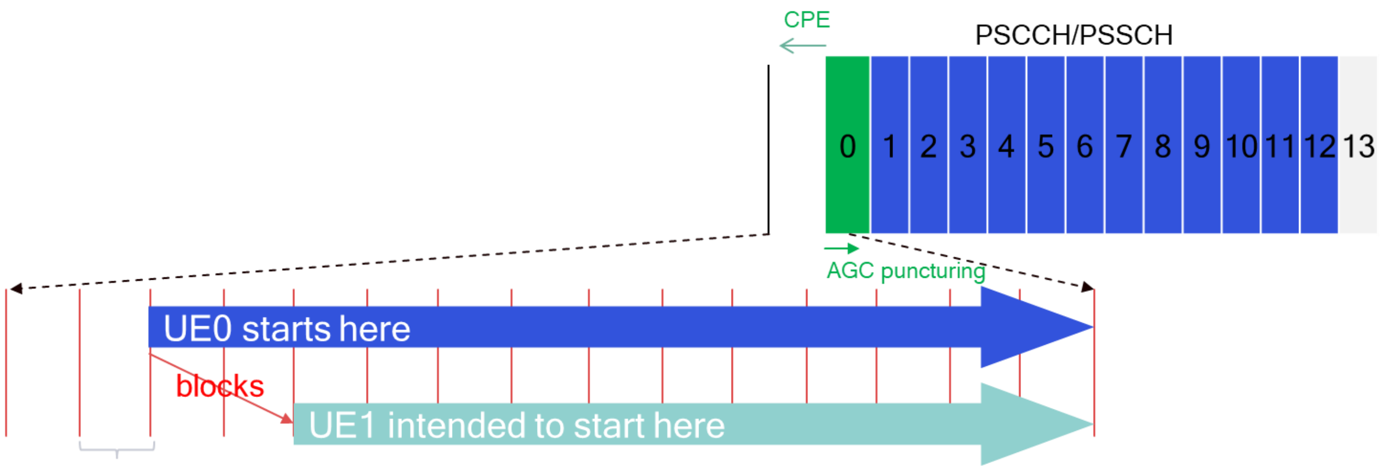
- COT sharing for PSFCH
  - Reduce AN delay and reTx overhead due to LBT failure
  - **A/N toward COT initiator**
    - Receiver performs type 2 LBT before PSFCH transmission toward the transmitter within the transmitter initiated COT
  - **A/N toward Transmitters other than COT initiator**
    - The A/N transmitter is receiving other PSSCH from COT initiator
      - In NR-U, the gNB sharing the COT from UE can transmit PDCCH (control signaling) to other UEs. So, it should be ok if the A/N transmitter is also receiving other PSSCH from COT initiator



- COT sharing for PSSCH/PSCCH
  - Reverse link toward the nodes including COT initiators
    - Unicast for data coming back or groupcast/broadcast including the COT initiator
    - Similar behavior as in Uu UL to DL COT sharing

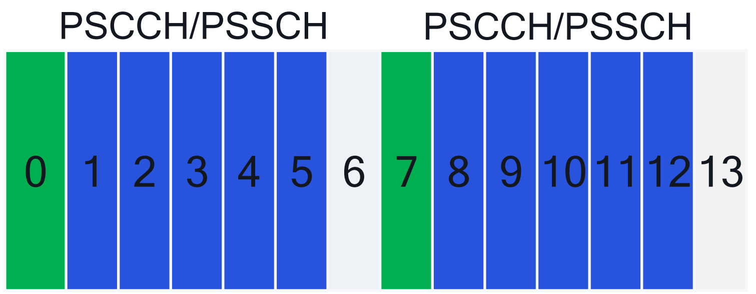
Channel Access: Contention Slot

- Intra-RAT LBT collision
  - For SL-U operation, there can be multiple UEs contending for channel access at the same time
  - If the intended transmissions start at the same time, there can be collisions
  - Apply to both type-1/2 LBT
- Leverage NR-U CG-PUSCH design to introduce contention slots before the intended transmission
  - Multiple contention slots (9us each) introduced ***before slot boundary with CPE*** and *after the slot boundary with **AGC puncturing***, and each UE hashes to one of the starting points
  - Allow UE hashed to an earlier starting point to start transmission earlier to stop another UE hashed to a later starting point

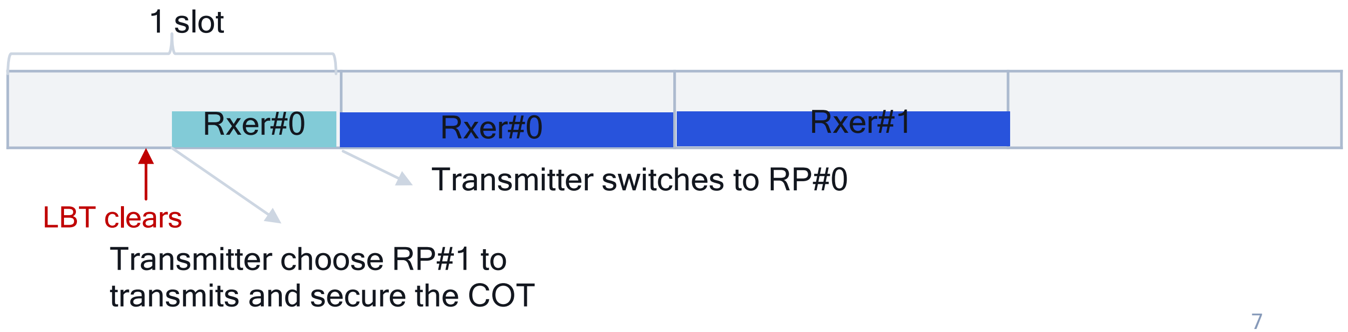


Slot Structure: Mini-slot for more starting points

- Introduce SL mini-slot structure to improve channel access success rate when competing with async WIFI
  - At least two half slots
  - Mini-slot structure with AGC symbol and PSCCH/PSSCH (miniature of a SL slot)
  - Rate match PSSCH to close the mini-slot end gap for mini-slot burst

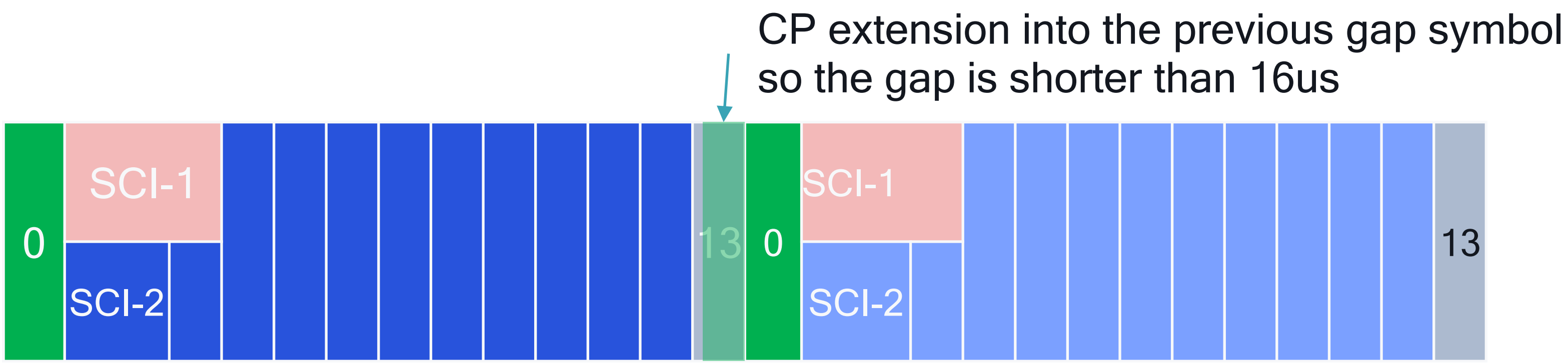


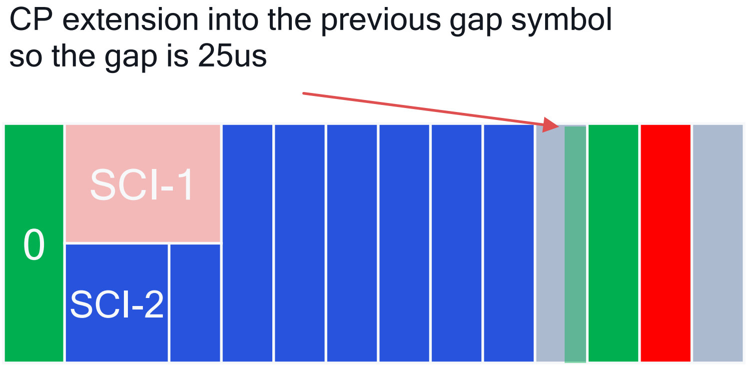
- Mini-slot RP & full-slot RP switching at Transmitter
  - Improve slot-based access vs the async access in WiFi
    - Mini-slot RP provides more chances to access the medium
  - Transmitter starts with mini-slot RP with more TX starting points after LBT and switch to full-slot RP for efficiency
  - Based on UE capability, receiver to monitor both the mini-slot & full slot RP, or full slot RP only
  - Transmitter may schedule to transmit high capability receiver with mini-slot RP at the beginning of the data burst to improve channel access successful rate



Slot Structure: Continuous Transmission Enhancements

- Use CP extension of the AGC symbol into the gap symbol of the previous slot
  - Essentially make the AGC symbol longer
  - Can either fill the entire gap symbol (full AGC symbol repetition), or partially, but at least long enough to make sure the gap is less than 16us, to keep the access of the channel
- When source and destination are the same, the gap symbol can be replaced with data and only transmit one set of SCI-1/SCI-2.
- For PSFCH transmission, from the experience of NR-U, the following are possible
  - Share another SL transmission COT with Cat 1 LBT (no LBT) if gap is no more than 16us
  - Share another SL transmission COT with Cat 2 LBT if gap is 25us
  - Share another SL transmission COT with Cat 2 LBT if gap is longer than 25us
  - Acquire its own COT
- For PSFCH, CP extension can be used to maintain the right length gap to match the LBT type
  - The **SCI triggers the PSFCH transmission will be responsible to indicate the channel access type and CP extension duration** (just as in NR-U)





Interlaced waveform for PSCCH/PSSCH

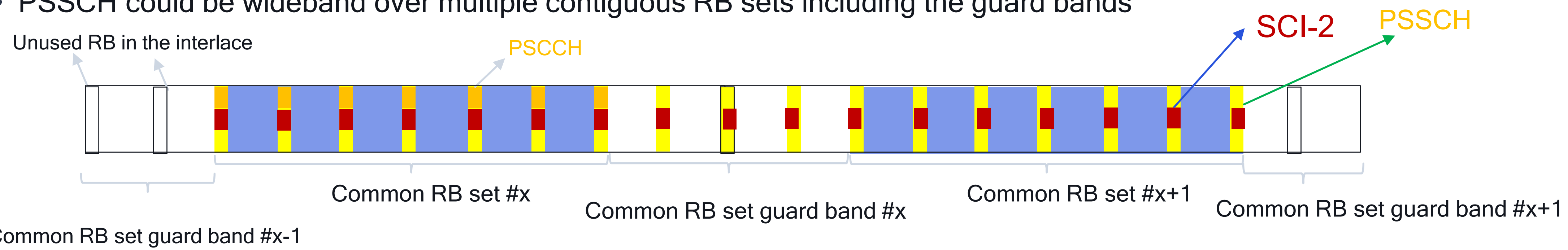
- We need interlaced waveform for the PSD & OCB requirement in unlicensed band and need to map the waveform to SL resource allocation framework

- Interlace waveforms for PSCCH/PSSCH directly leverage NR-U design
  - 15KHz SCS case: 10 interlaces
  - 30KHz SCS case: 5 interlaces

- Basic unit of allocation: subchannel defined as 1 interlace in one subband (~20MHz, aka RB set)
  - Depends on the guard band setting, the number of RBs in a subchannel is not fixed, i.e., approximately 10 RBs but can be more or less

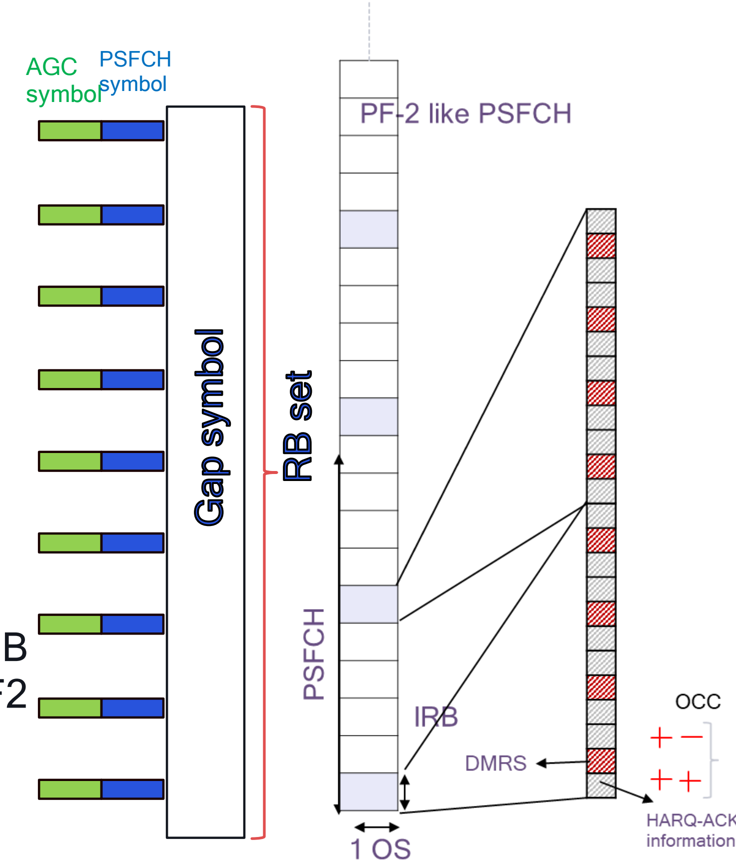
- PSCCH resource mapping
  - Occupies **one** interlace within **one** RB-set and TDM/FDM with interlaced PSSCH
  - SCI-1 rate matched to the common RB-set within a 20MHz subband

- PSSCH resource mapping
  - TDM/FDMing with PSCCH with the PSCCH as the **leading interlace**
  - SCI-2 and data PSSCH is rate matched to common RB set(s) indicated by SCI-1
  - PSSCH could be wideband over multiple contiguous RB sets including the guard bands

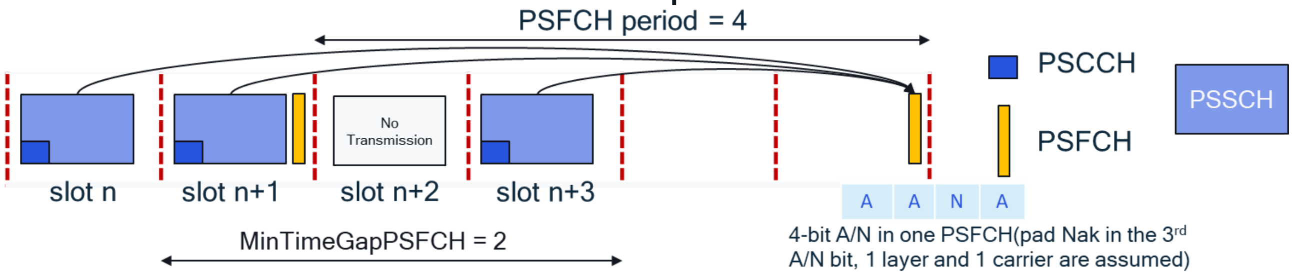


PSFCH Waveform and HARQ Codebook

- <u>**Interlace PF0 PSFCH**</u> (IRB based full interlace)
  - Cyclic shift ramping across IRBs
  - 1 AN bit per interlace per CS pair
- <u>**Interlace PF2 PSFCH**</u>: OFDM waveform using all RBs in the interlace
  - Introduce PUCCH Format 2 for PSFCH.
  - Support type-1/2/3 HARQ CBs
  - To improve user multiplexing, apply frequency domain OCC-2/4 on PF2 PSFCH data symbols and DMRS
  - Increase the UE or PSFCH multiplexing capacity by 2/4 times
- Using interlaced PF0 for feedback could lead to inefficient utilization of resources. For eMBB traffic, we may need HARQ codebook designs so the AN's for multiple TBs can be carried via PF2 PSFCH in one PSFCH transmission
- <u>**Type-1/2 HARQ CB with fixed timeline**</u>
  - Common PSFCH RP with period 1/2/4
  - Multi-bit PSFCH interlace waveform (PF2) to carry type-1/2 HARQ codebook
  - For type-2, SAI can be introduced in SCI to counter SCI missed detection problem



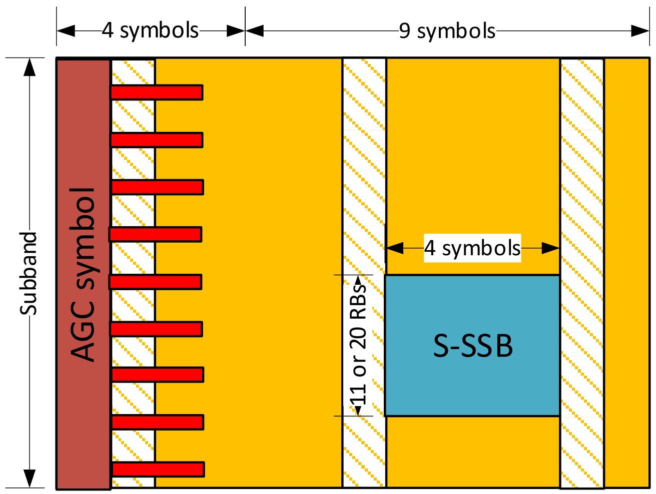
Type-1 HARQ codebook



PSSCH in slot n, slot n+1 and slot n+3 are transmitted from the same source UE.

NR SSB multiplexed with PSCCH/PSSCH, Time Domain

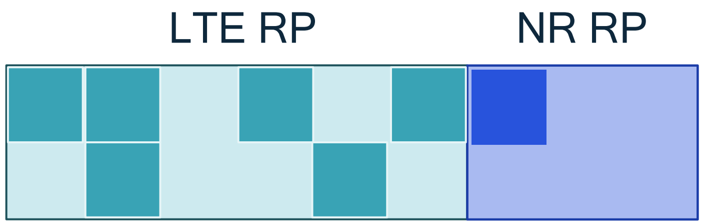
- Rel.16 S-SSB is very difficult to multiplex with PSCCH/PSSCH in a subchannel
  - S-SSB slots are not part of a resource pool in Rel. 16.
  - PSCCH may be able to rate match around S-SSB, but this involves blind detection of rate matching given a receiver does not know the PSCCH is multiplexed with S-SSB or not
    - This design may be limited to full interlace (all) transmission of PSCCH/PSSCH
- Reuse NR Uu SSB structure (4 symbols and 20 RBs), but single SSB per slot with SSB avoids PSCCH, DMRS of PSSCH and SCI2
  - SSB avoids first 4 symbols (AGC symbol, up to 3 symbols for PSCCH)
  - SSB avoids symbols 1, 6, and 11, which are DMRS locations with 3 DMRS
    - This DMRS pattern has 4 symbol gap between DMRS, so an SSB can fit in
    - Only certain DMRS pattern can be used for SSB transmission



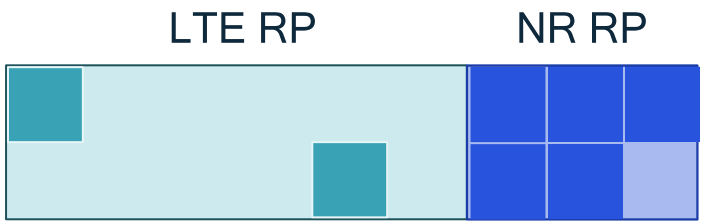
Co-channel Coexistence for LTE SL and NR SL

LTE SL and NR SL Coexistence in Release 16/17

- To support co-channel coexistence of LTE and NR SL using Release 16/17:
  - Option 1: LTE SL and NR SL resource pools (RP) could be TDMed:
    - ✗ Requires changes to existing LTE SL systems pre-configuration, which is not possible.
    - ✗ Inflexible and cannot adapt to changes in LTE SL and NR SL device mix.

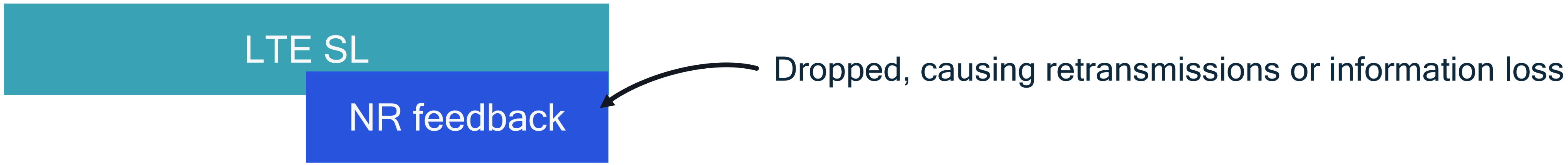


Initial deployment:
High LTE RP utilization, few NR devices



Future state:
Underutilized LTE RP, Congested NR RP

  - Option 2: In-device coexistence mechanism from Release 16 could be used:
    - ✗ Drops transmission/reception in case of conflict instead of avoiding conflicts, particularly detrimental for feedback.
    - ✗ Significantly degrades the performance of either LTE SL or NR SL operations of equal priority.



Dynamic Co-channel Coexistence

Basic Scheme

- The set of resources available for NR SL transmission is dynamically updated.
  - More resources are available for NR SL when LTE SL traffic is low and the number of NR SL devices increases.
  - Fewer resources are available for NR SL when LTE SL traffic is high and the number of NR SL devices decreases.
- NR SL devices are attempting to receive NR SL in all slots of the resource pool.
- Each NR devices determines the set of resources independently.
  - A basic set of NR SL transmission resources is provided, this set includes the PSFCH resources.
  - Additional resources for NR SL resources are updated dynamically.
- NR SL devices receive LTE SL SA, same as in Rel-16 in-device coexistence.
- No changes to LTE SL devices.
  - Existing LTE SL RSSI measurements can also avoid collisions with periodic NR transmissions.

Dynamic Co-channel Coexistence

NR Transmission Resource Set

- Any slot/sub-frame can be fully allocated to NR SL, LTE SL or FDMed between NR SL and LTE SL.
  - An NR SL PSFCH slot is a full NR SL slot, i.e., no FDM with LTE SL.

Smaller number of NR devices. Fewer resources are available for NR SL transmissions.

Orange is a full NR SL PSFCH slot, blue is a full NR SL normal slot, green is a full LTE SL slots

Larger number of NR devices. More resources are available for NR SL transmissions.

Orange is a full NR SL PSFCH slot, green is a full LTE SL slots, blue is a full NR SL normal slot, light green is a FDM slots

Discussion on Co-channel Coexistence

- The Rel-16 in-device coexistence is a coarse tool for co-channel coexistence.
  - It does not try to prevent conflicts, only resolves them by dropping operations.
  - The UE's choice of either performing LTE SL or NR SL operations will degrade the other RAT's performance.
- Dynamic co-channel coexistence provides better control over coexistence.
  - It tries to prevents conflicts from occurring in the first place.
  - This permits SL operations to take place on one RAT even if they have lower or equal priority than the other RAT's operations.
- Dynamic co-channel coexistence balances LTE SL and NR SL performance.
  - Future proof by adapting dynamically to the UE type distribution and traffic load in the system.
  - Ensures a baseline performance for NR SL by permitting feedback transmission, avoiding unnecessary retransmission.
- Dynamic co-channel coexistence does not require changes to LTE SL devices.

Carrier Aggregation and FR2

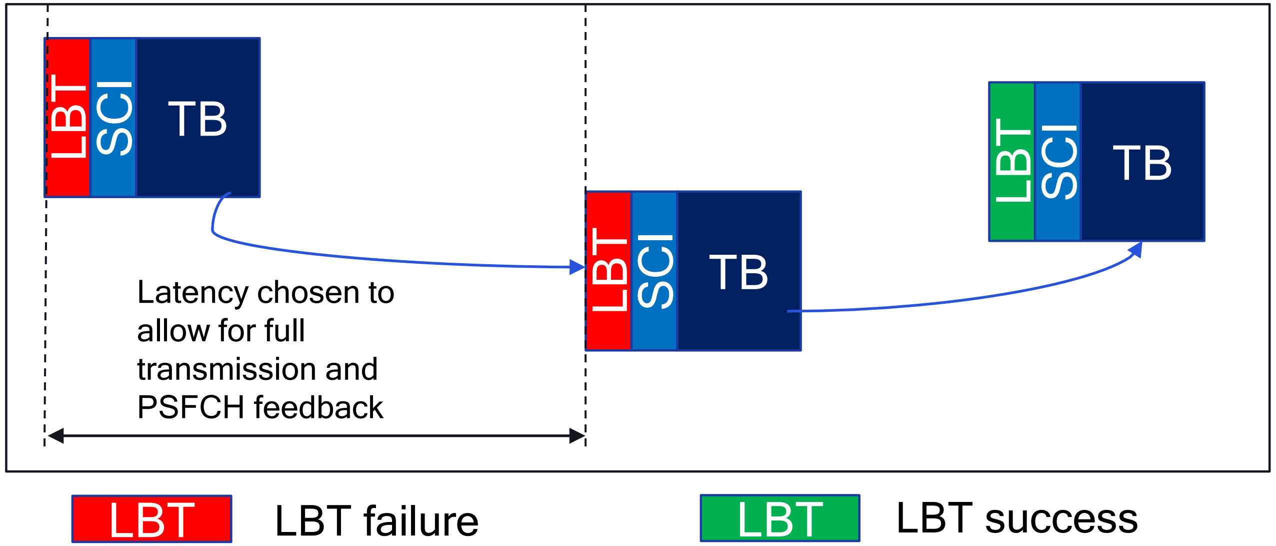
FR2 and CA Support for Sidelink

- Motivation:
  - Rel-16/17 SL mainly focused on V2X, public-safety, and power savings for commercial applications. Rel-18 expands support for commercial applications, including NCIS and XR, which require Gbit/sec throughput and low latency.
  - Offloading Uu traffic via Sidelink wherever possible can increase spectrum utilization efficiency and reduce latency.
  - FR2, with higher spectrum availability, is an excellent fit to fulfil these demands of throughput and latency.
- Key features to introduce for Rel-18 beam management:
  - Beam-management is required to overcome higher pathlosses in mmWave.
  - Beam management should include initial beam-pairing (analogous to SSB-RACH association in Uu), beam maintenance/refinement/update, and beam failure detection & recovery.
  - Include supporting features to enable these functions, such as standalone CSI-RS and L1-RSRP reports on SL.
- Key features to introduce for Rel-18 CA:
  - CA enables Gbit/sec throughputs by allowing larger BW operation.
  - CA should include CC activation/deactivation.
- Both beam-management and CA have been in NR Uu since Rel-15. The Uu designs can be reused for SL wherever possible.

RAN2 Aspects

Impact of LBT failures

- LBT failure possibility of SL transmissions causes missed transmission opportunities and unexpected loss of data
- In the baseline, LBT failure is no different from a NAK indication/missed feedback. Conventional retransmission on scheduled resources, if any is available.



Mode 1

- Retransmission on scheduled resource after LBT failure causes unnecessary latency, data loss and high overhead due to gNB signalling to schedule retransmissions.
- gNB cannot detect LBT failures and thus may keep scheduling SL transmissions on a congested subchannel.
- Lost PSFCH feedback due to LBT causes a large number of potentially HARQ retransmissions significantly limiting the capacity

Mode 2

- In Mode 2, future reservations are not protected from Inter-RAT interference and LBT failures.
- Due to WiFi asynchronous access, UEs in a WiFi device proximity will be starved due to continuous LBT failures and unused reservations.
- Furthermore, UEs that suffer from continuous LBT failures perform multiple unfulfilled reservations which limits the capacity of the networks due to reduced resources available to other UEs.

Solutions for LBT failures

- For better access to the channel when shared with other RATs, we suggest to study enhancements to resource allocation:
  - To improve opportunities for accessing the channel
  - Applicable to both mode 1 and mode 2

- Consistent LBT failures can cause significant loss and/or delay of data. Therefore, we suggest to introduce consistent LBT failure detection and recovery:
  - NR-U scheme can be used as a baseline.
  - Reporting and recovery can be different for Mode 1 and Mode 2

- Other NR-U mechanisms can also be considered for SL-U:
  - E.g. CG retransmission

SL-CA

- Supporting SL-CA
    - In coverage (IC) and out of coverage (OoC), e.g., resource allocation mode 1 and mode 2.
    - All cast types, e.g., unicast, groupcast and broadcast.

- SL-CA design considerations
    - Base line from SL-CA for LTE V2X in Rel 15.
    - Support PC5 RRC connection
    - Support HARQ operation and other MAC procedures such as BSR/SR, CC activation/deactivation, and MAC control signaling for CSI reporting, configured grant, BSR reporting

FR2 Support on SL

- PC5 RRC support for FR2 operation
  - Identify and define new IEs for SL FR2 operation (e.g. beam management and L1 beam measurements/reporting)
- Support MAC procedures and signaling necessary for FR2 operation, such as
  - Initial beam pairing – RACH-like procedure
  - TCI state activation/deactivation
  - Beam failure detection (BFD)
  - Beam failure recovery (BFR)
  - CSI-RS activation/deactivation
- Consider optimizations for beam management, measurements, and reporting in case of multiple RRC connections among a pair of UEs (i.e. multiple services) to take advantage of the knowledge that the physical link is common

Thank you!

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