Proposals for facilitating co-channel and adjacent channel coexistence in 802.16 LE

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Purpose:

Facilitate co-channel and adjacent channel coexistence for 802.16 LE.

Proposals

- The proposals are primary for facilitating the 802.16 LE coexistence deployment
  1. Nationwide 802.16 LE system data base
  2. Mechanisms for co-channel or adjacent channel coexistence
     a) Coexistence mechanism for network initialization and synchronization phase
        - E.g. Scan, Ranging
     b) Coexistence mechanism for normal operation phase
        - E.g. data or messages transmission and reception

Nationwide 802.16 LE system data base (1)

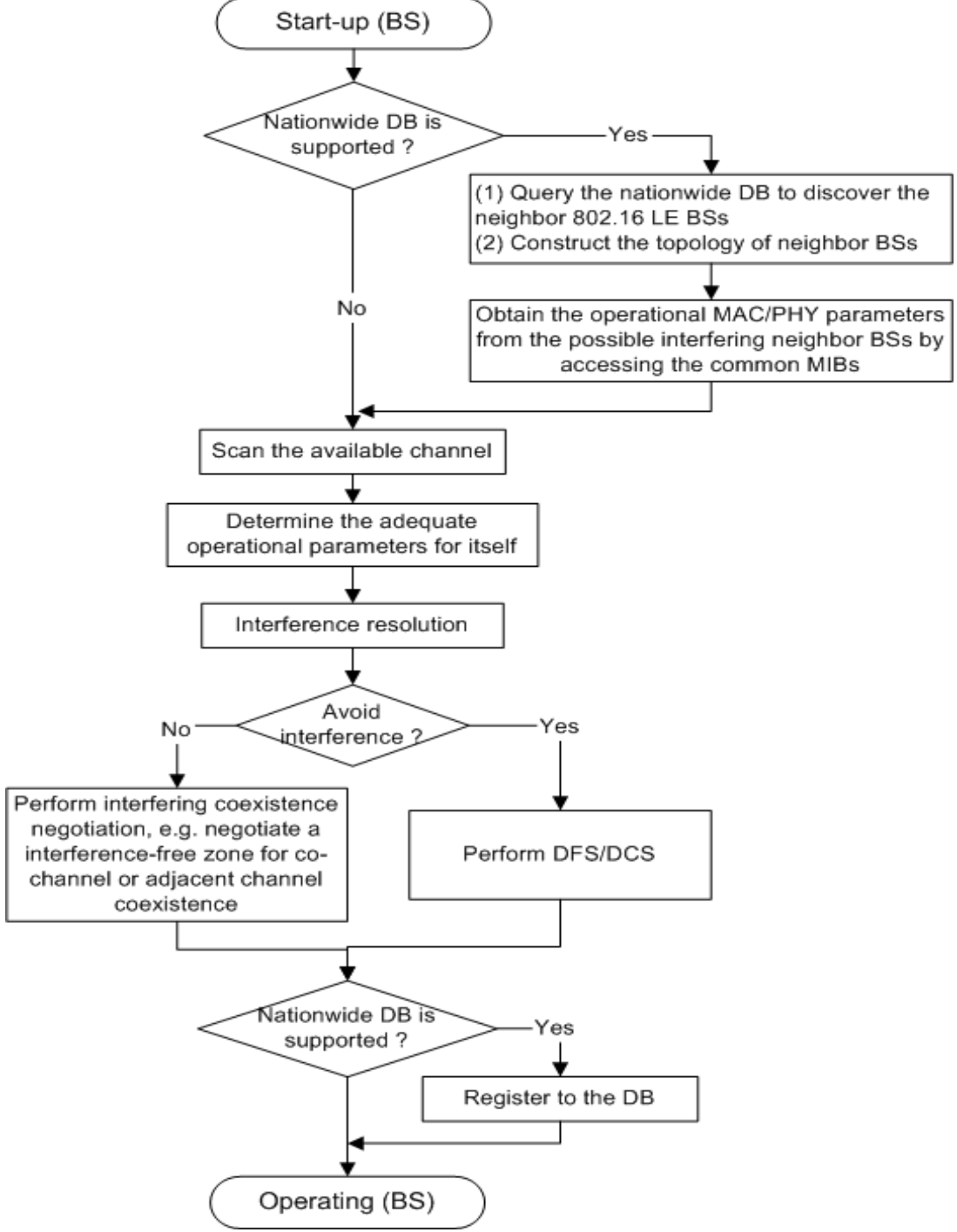
- **A nationwide 802.16 LE system data base**
  - Since 802.16 LE BSs is not like 802.11 APs, it is reasonable to have a nationwide management system.
  - Each operating 802.16 LE BS with or without GPS can register its
    - geographic information, e.g. latitude and longitude;
    - system parameters such as planned cell coverage and
    - Network Management address

    to a nationwide data base.
  - The Ad-hoc systems without MIBs and Network Management functions can also register its hosting system to this data base.
  - Merits
    - Facilitate the neighbor discovery (topology discovery) and neighbor negotiation for the newly installed 802.16 LE BSs.
    - Avoid the co-channel or adjacent channel interference in advance while setting up the new systems.
    - Facilitate the authentication and authorization between 802.16 LE BSs while querying the data base.
    - Facilitate Share RRM scheduling between the 802.16 LE BSs.

Nationwide 802.16 LE system data base (2)

- Issues
  - Who will maintain this data base ?
  - Co-work with 802.16g ?
  - Detailed mechanisms for registering, updating and querying the data base.
  - The contents of the registration information.

The proposed start-up procedures for the BS



Why we need mechanisms for co-channel or adjacent channel coexistence

- Limitations of interference avoidance
  - Overhead of channel switching may be costly
    - All the SSs need to re-synchronize with BS.
      - Especially when the traffic loading of BS is heavy.
  - Some coexistence impacts may be caused by the user mobility, thus the interference is not permanent.
  - In some cases, e.g. more than two BSs may coexist, the free channel may not enough !
  - For only few SSs in the overlapping service coverage, switching the operating channel may not be necessary.

Mechanisms for co-channel or adjacent channel coexistence

- While the BS is operating, the mechanisms for co-channel or adjacent channel coexistence can be divided into two classes:
  - For network initialization and synchronization phase
    - Make sure that the interfered SS can associate/re-assoiciate with the BS.
    - Make sure that the interfered SS can report its coexistence condition and move to the interference-free zone.
  - For normal operation phase
    - Make sure that those interfered SSs can operate correctly.

Coexistence mechanism for network initialization and synchronization phase

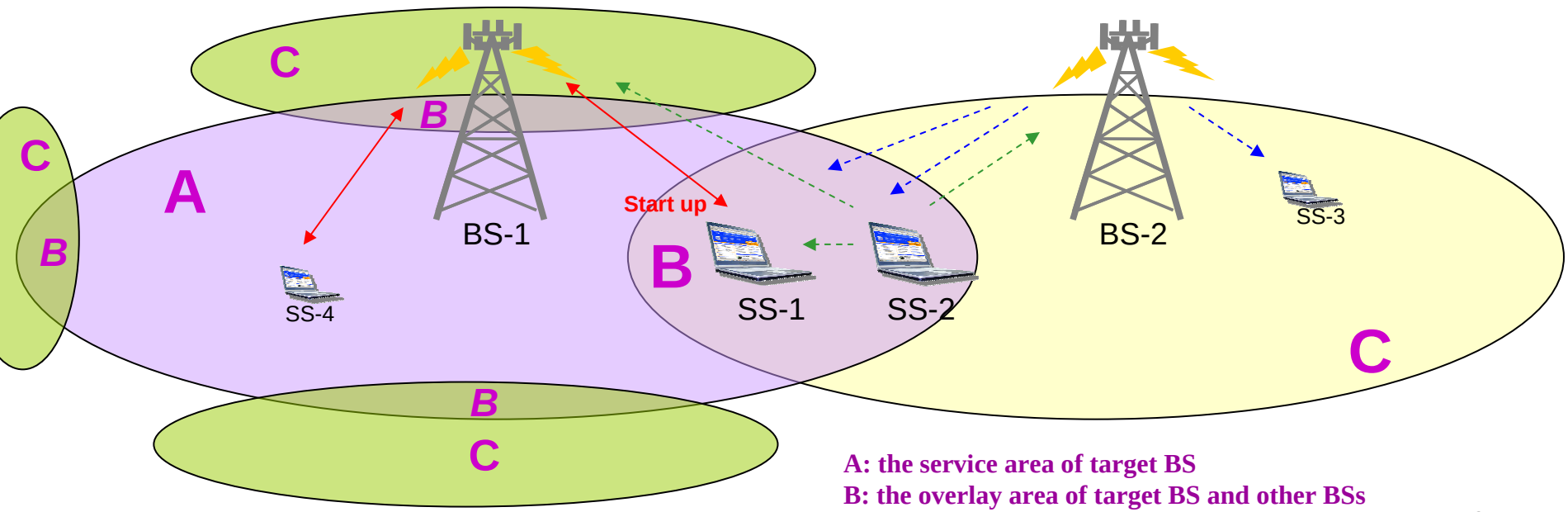
- Problem definition
- Scenario description
- Analysis

Problem Definition

- The 802.16 SS state can be divided into two 2 phases
  - Network initialization and synchronization phase
    - Network initialization (Scan, Ranging, …)
  - Normal operation phase
    - Maintain connectivity (obtain DL/UL-MAP, XXX-RSP, and transmit XXX-REQ)
    - Tx/Rx (transmit/receive data bursts)
- The interference would impacts SS on the 2 phases
  - Network initialization and synchronization phase
    - Cannot associate with BS and establish radio link to use service (1)
  - Normal operation phase
    - Failure in maintaining network connections (2)
    - Suffer from the high BER or failure of transmission (3)

Scenario – Network initialization and synchronization phase

- The SS-1 in the zone “B” powers up and scans channels for association
  - Interferences problems
    - The downlink signal generated from other BSs
    - The uplink signal generated from the nearby SSs



A: the service area of target BS
B: the overlay area of target BS and other BSs
C: the service area of the neighboring BS

Interference cases analysis (1)

	Case 1 - DD	Case 2 - DU		Case 3 - UU		Case 4 - UD
BS-1						
SS-4 (Zone A)						
SS-1 (Zone B)						
BS-2						
SS-2 (Zone B)						
SS-3 (Zone C)						

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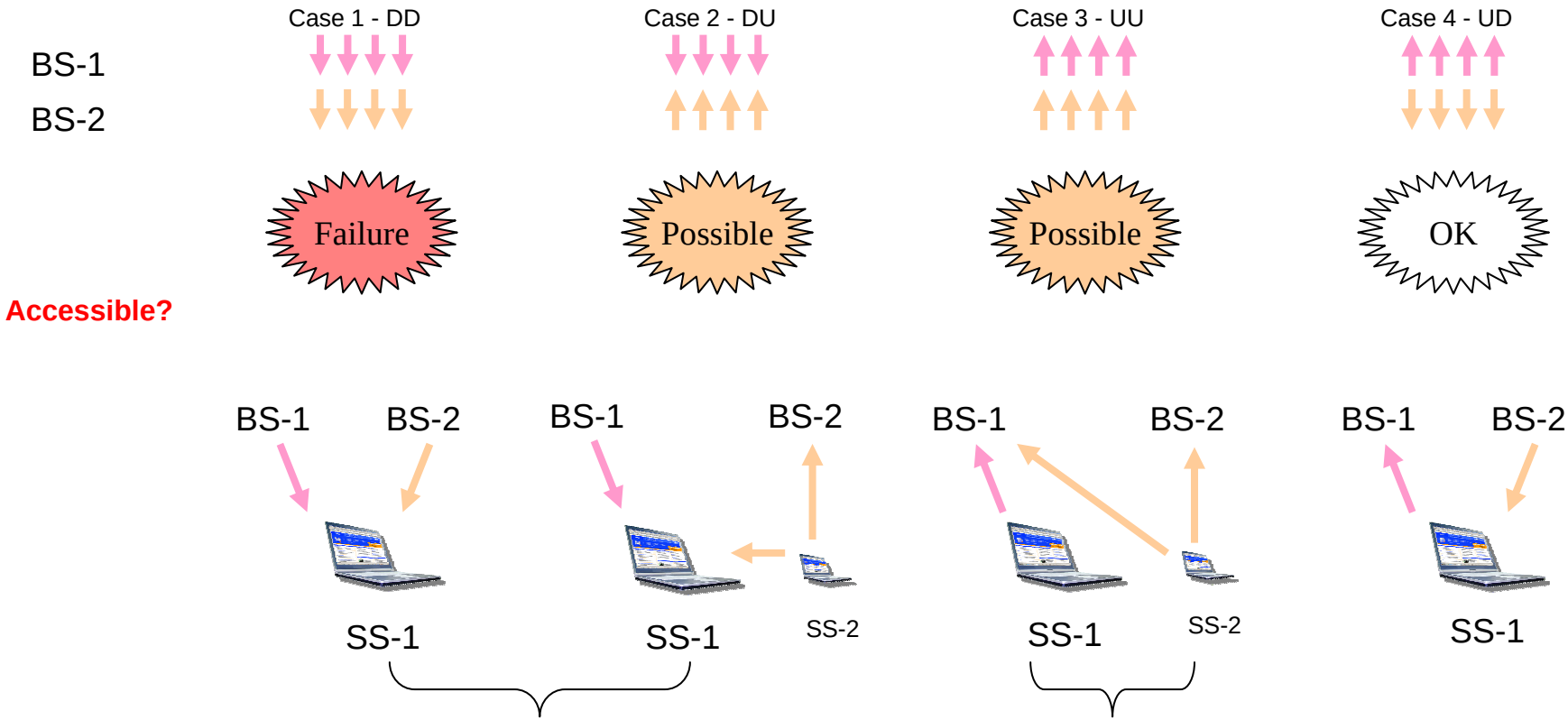
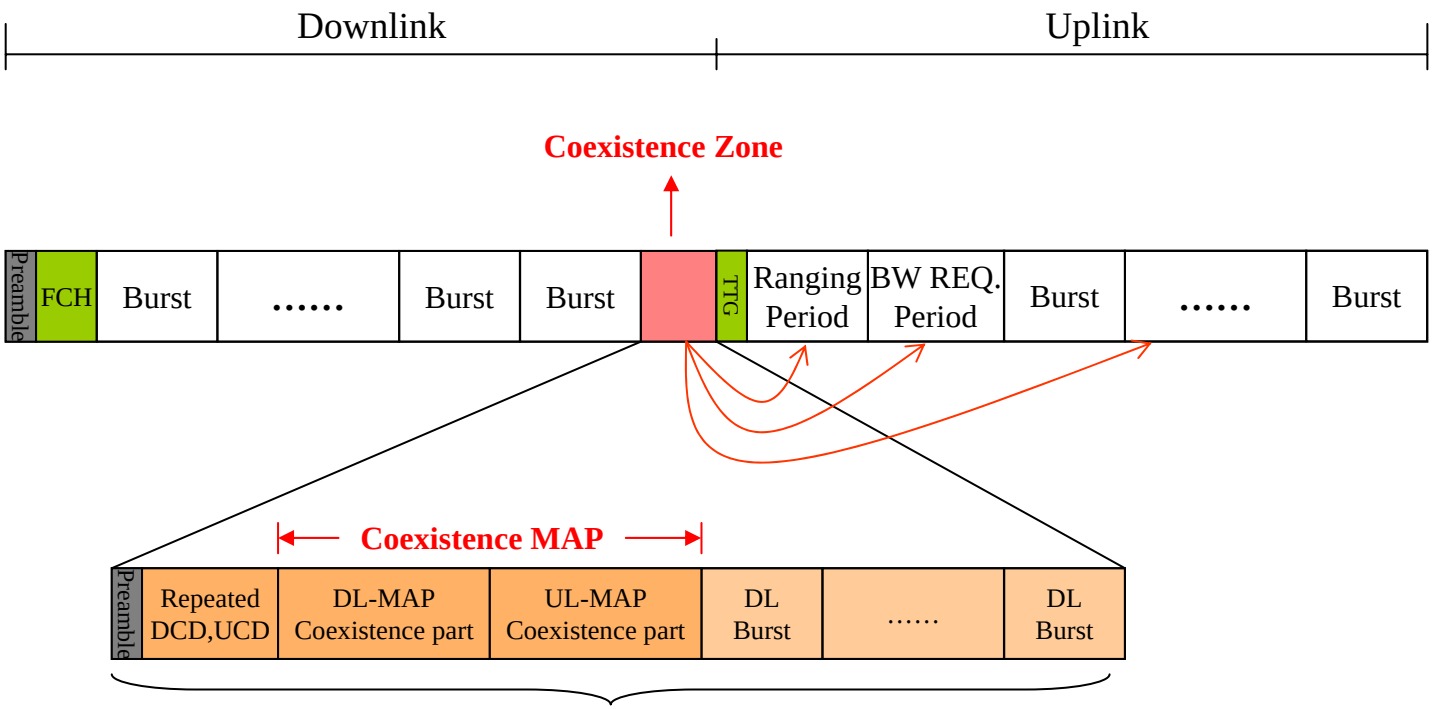
DD: DL v.s. DL DU: DL v.s. UL UU: UL v.s. UL

Interference cases analysis (2)



Proposed Modification (1)



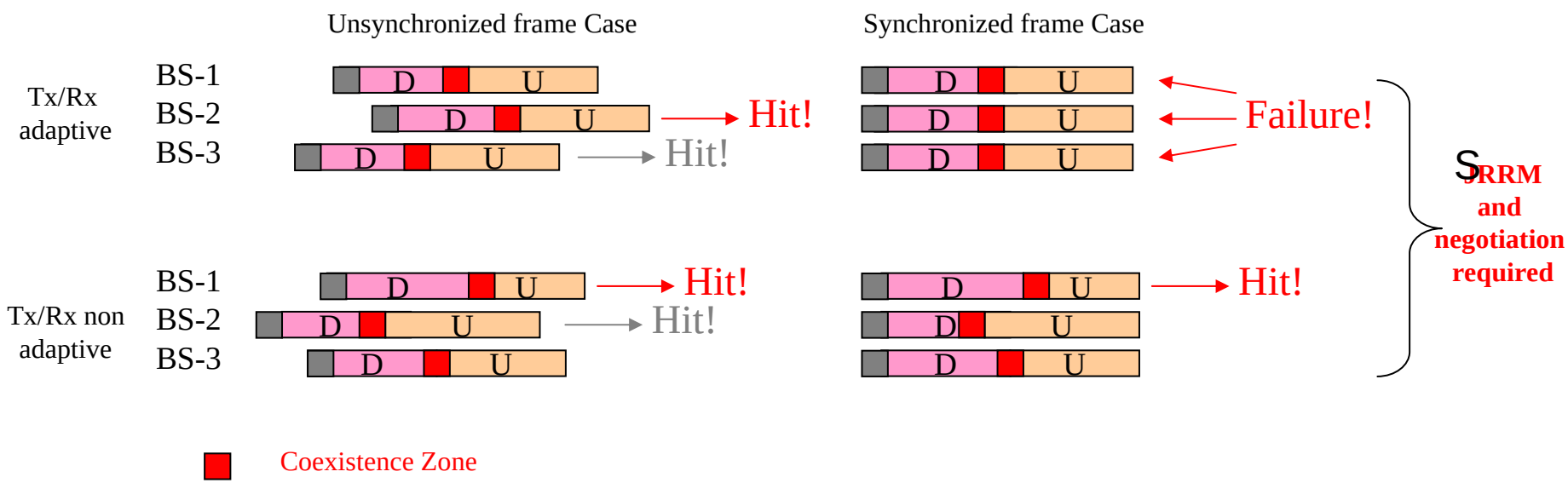
For the SS that is interfered and the interference is not resolved

Proposed Modification (2)

- Coexistence sub-map
  - Allocated for the SSs in the zone B, which are interfered and the interference is not resolved, to entry or synchronize the network
  - Allocated in the last burst of the downlink subframe
    - Increase the opportunity for SSs to obtain the system information
      - DCD, UCD
      - Ranging/BW-REQ contention period
      - DL/UL burst location for receiving/transmitting message
  - Allocated dynamically by BS depends on its traffic load

Improve the coexistence performance

- Increase the hit ratio for the SSs of zone B to obtain the system information



Compatibility

- Not effect the transmission of the pure 802.16 SSs
  - View the coexistence zone as the data burst for others
- Identifying user from Coexistence Zone

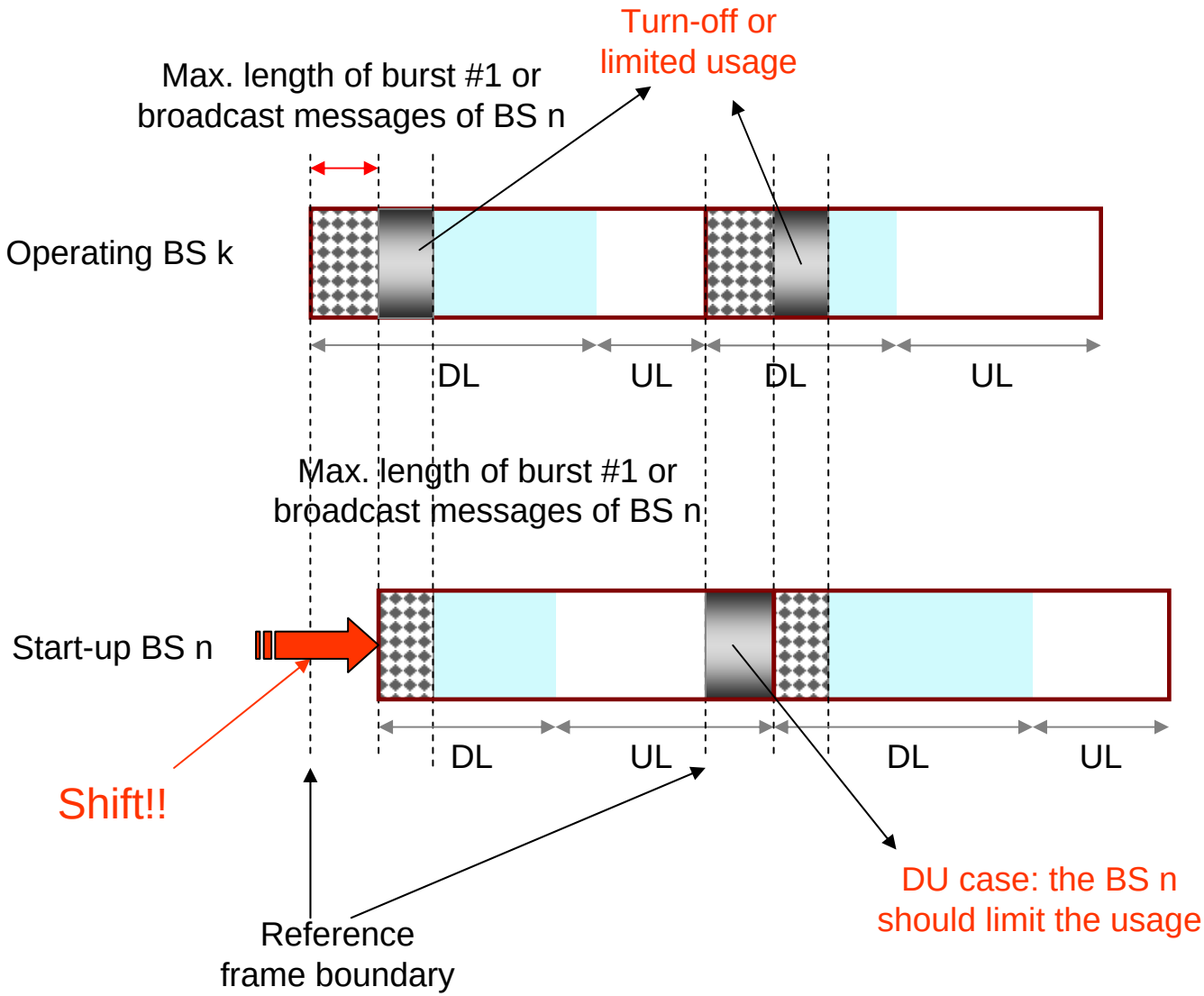
  (Because SSs from zone A and B will content in the same period)
  - New Management Message Type (0~255) for the Coexistence MAP
    - SS can identify that the current map is the pure map or coexistence sub-map
  - New parameters (e.g. new TLV value) in RNG-XXX message to identify the SSs of zone A and B
    - BS can arrange the timeslot allocations for the SSs
- Coexistence and Regular zone handover

  (If the radio condition changes, e.g. due to mobility)
  - BS can re-allocate the timeslots for the SSs in the zone B, and all SS should obtain the pure MAP to see if it is requested to handover to standard zone after the DFS procedure
  - New message for handover ?

Discussion

- The issues
  - Ease the coexistence problems of interfered SSs
  - The failure probability is unpredictable.
  - Share-RRM is still needed in the synchronized cases.
- If the BS obtains the neighbor topology from the nationwide data base during start-up procedures, it can further shift the frame boundary itself so that its first burst can be staggered with the first burst of another BS.

Staggered first burst



Discussion

- There is no need to repeat the broadcast information.
  - Save limited radio resource
- The mechanism to stagger first burst relies on BS join scheduling or Share RRM.
- While the BS is operating, this mechanism may be not easy to implement.

Coexistence mechanism for normal operation phase (1)

- In IEEE C802.16d-04/30, it has proposed a mechanism to create a interference-free interval among the coexisting BSs operating at adjacent channels.
  - The inter-BS synchronization can be achieved within a few microseconds
    - CDMA2000 [2] is synchronized with the Universal Coordinated Time (UCT). The forward link transmission timing of all CDMA2000 base stations worldwide is synchronized within a few microseconds.
  - However, it assumed that
    - All the MAC frames having the same duration of DL (downlink) Tx (transmit) and UL Rx (receive) intervals.
    - Only adjacent channel interference will be considered; for the second adjacent channel, filters should clean the spectrum.
    - Furthermore, the method proposed in IEEE C802.16d-04/30 does not consider the user distribution.

Coexistence mechanism for normal operation phase (2)

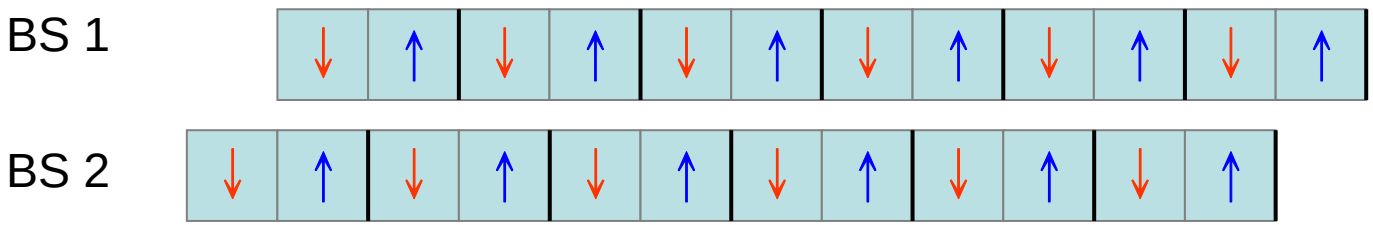
- Some identical assumptions in this proposal
  - Frame structures between coexisting BSs should be synchronous.
  - There is no external coordinator.
- Some differences between IEEE C802.16d-04/30 and this proposal
  - The duration of DL Tx and UL Rx intervals of different BSs can be different.
  - Both co-channel and adjacent channel can be applied in this proposal.
  - Create interference-free period, in time domain and frequency domain.
  - Adopt BSs join scheduling.

Coexistence mechanism for normal operation phase (3)

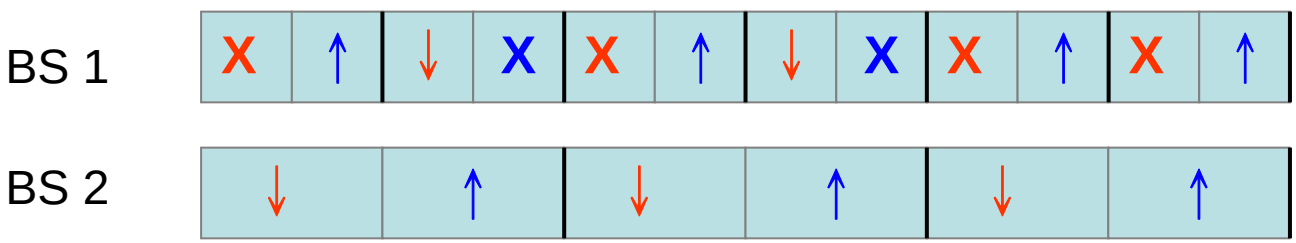
- The ***basic*** techniques that can let BSs coexist without switching channel and share the resources
  1. Radio resource shared by DL/UL interleaving
  2. Radio resource shared by frame on-off (time domain sharing)
  3. Radio resource shared by subchannel splitting (frequency domain sharing)
  4. Radio resource shared by hybrid mechanism

Radio resource shared by DL/UL interleaving

- The same frame duration and equal DL/UL intervals case

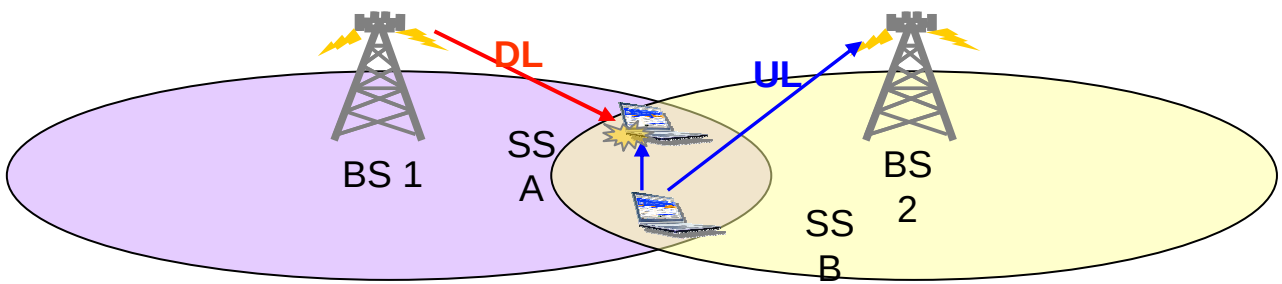


- The different frame duration case



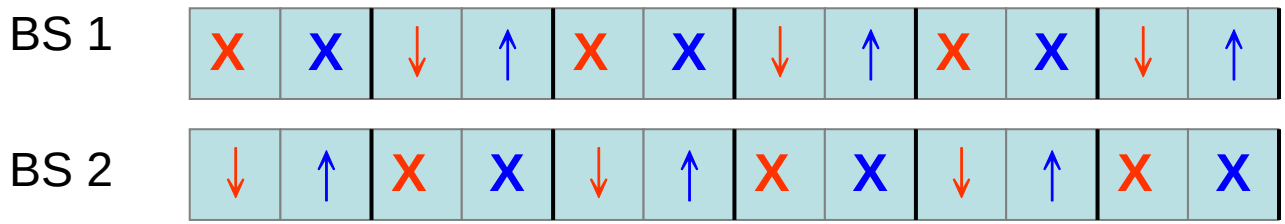
Discussion

- Merits summary
  - Avoid BS to ST and ST to BS interferences
  - Minimize the impact of coexistence on the throughput.
- Drawbacks summary of DL/UL interleaving
  - DL/UL interleaving only cannot avoid the interference caused by the neighbor STs from another BS.
  - In the scenario of different frame duration, the throughput will be reduced.
  - The performance and complexity of DL/UL interleaving will increase substantially in the case of time variant DL/UL boundary.
  - ***Coexisting BSs join scheduling*** is required for avoiding inter-ST interference.

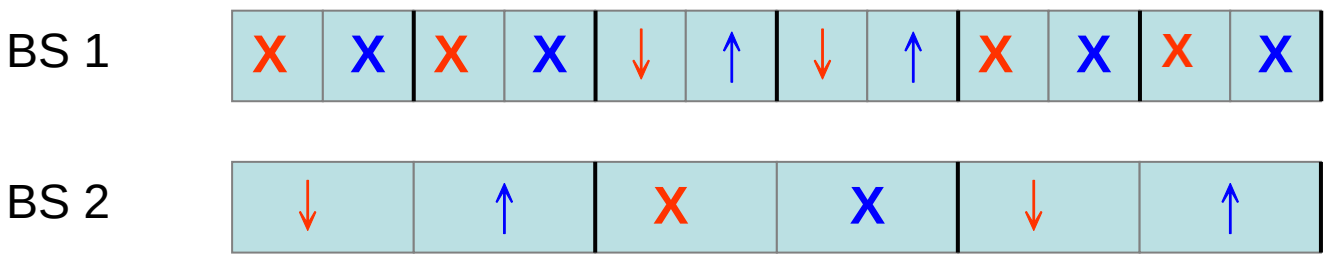


Radio resource shared by frame on-off

- The same frame duration case



- The different frame duration case

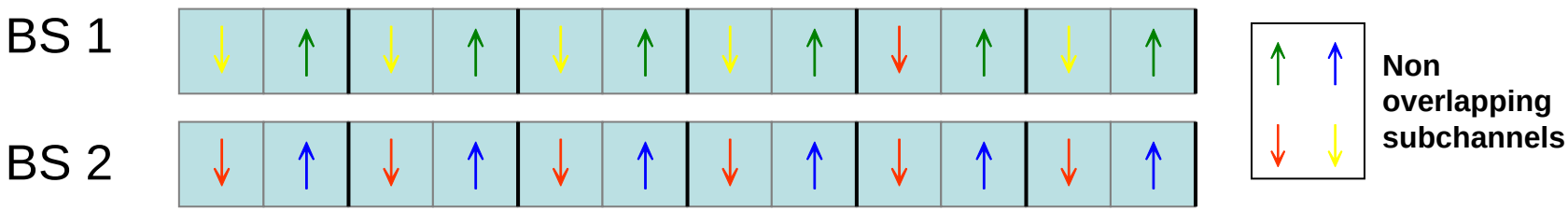


Discussion

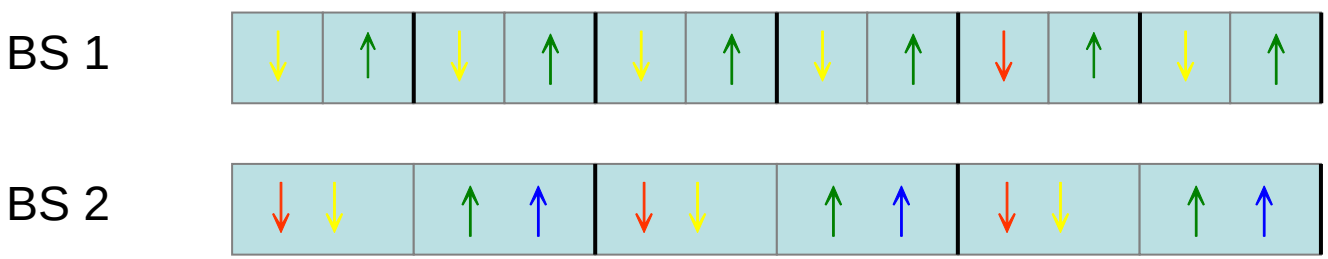
- Merits summary of frame on-off
  - Avoid BS to ST, ST to BS and ST to ST interferences
  - Easier to realize than DL/UL interleaving
- Drawbacks summary of frame on-off
  - The throughput will be reduced.
  - The coexisting BSs will shut down entire frame alternately for only few interfered STs.
  - ***Coexisting BSs join scheduling*** is required for maximizing the throughput.
    - Not entire subframe will be off, if the coexisting BSs join scheduling can be achieved.

Radio resource shared by subchannel splitting

- The same frame duration case



- The different frame duration case



Discussion

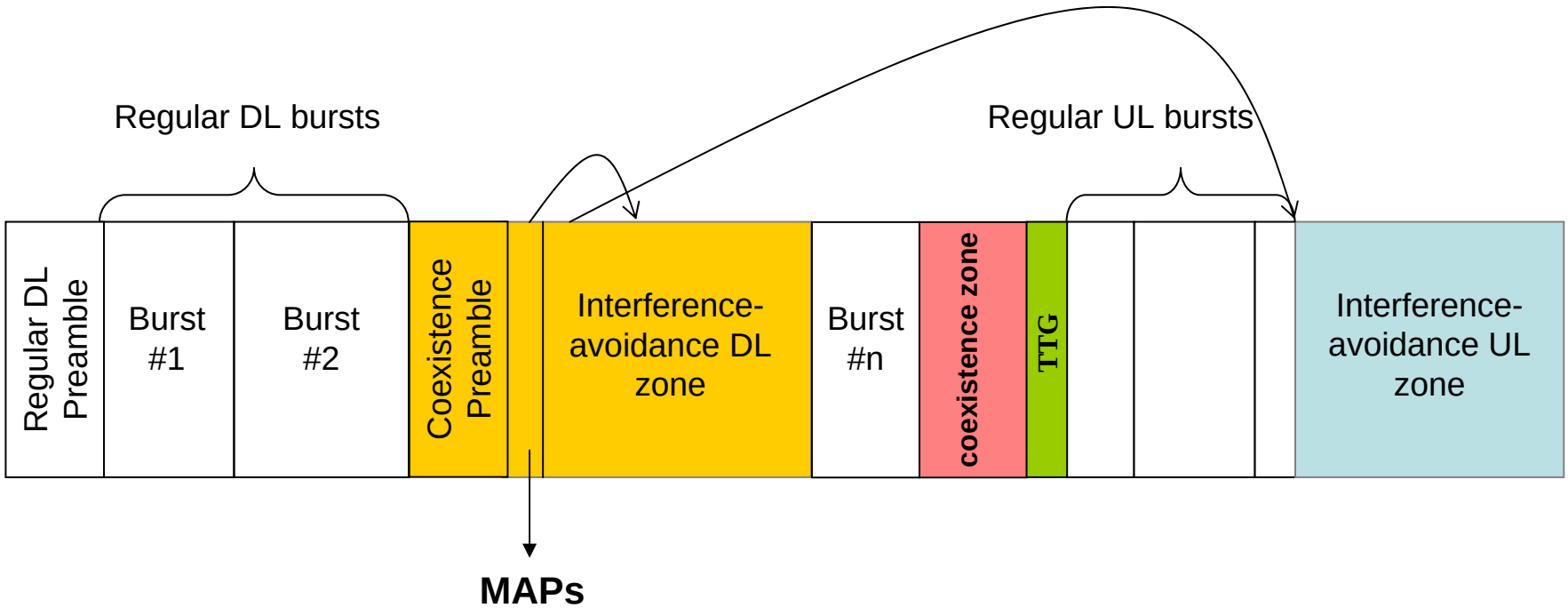
- Merits summary
  - Avoid BS to ST, ST to BS and ST to ST interferences
  - Minimize the impact of coexistence on the throughput.
- Drawbacks summary of subchannel splitting
  - Not suitable for all PHY modes.
    - But this method may be used by the OFDM/OFDMA PHY to avoid the adjacent channel operating at SC mode.
  - ***Coexisting BSs join scheduling*** is required for maximizing the throughput.
    - Certain subchannels will not be “off” during entire subframe (partial usage), if the coexisting BSs join scheduling can be achieved.

Utilization improvement

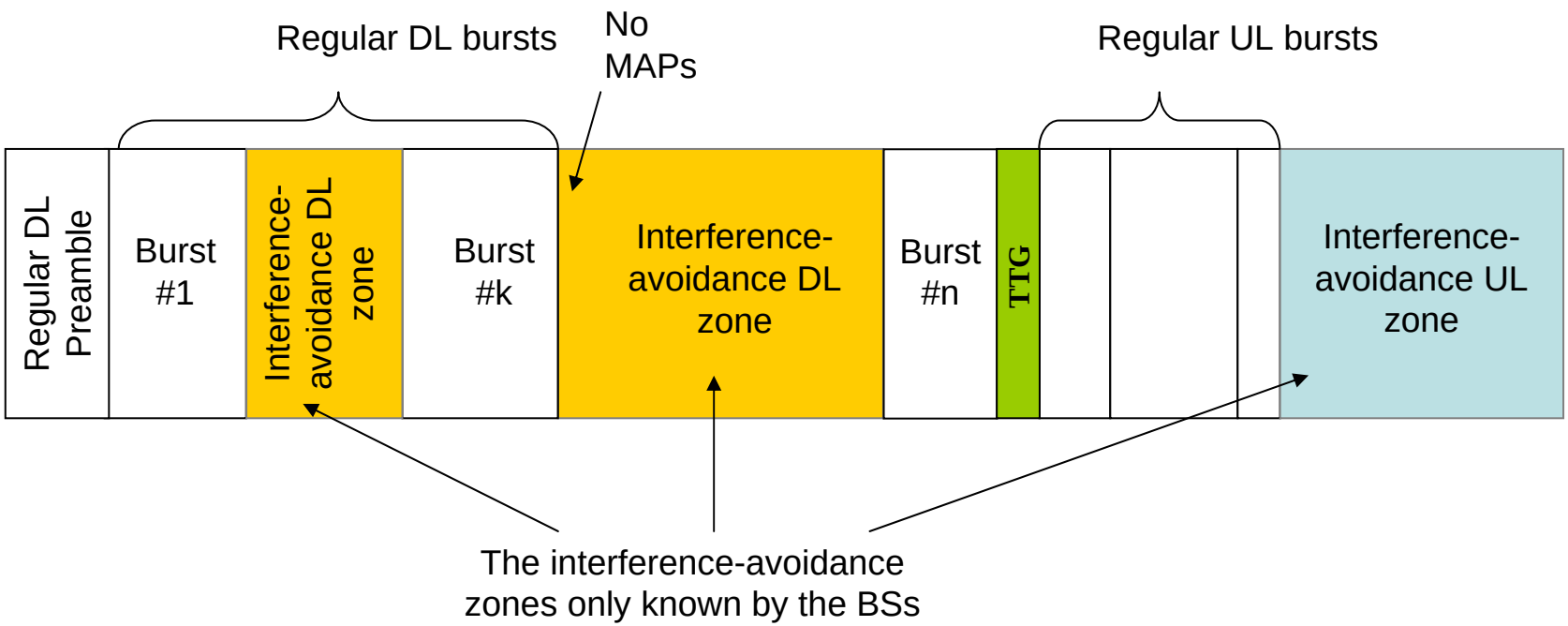
- **Coexisting BSs join scheduling**
  - If there are only few STs in the interfered overlapping service coverage, we could minimize interference and the throughput reduction through the join scheduling.
  - The STs are classified into two groups:
    - Non-interfered group
    - Interfered group
  - The different group of STs transmit and receive in the different “Zone”. (similar to AAS zone)
    - Regular zone for non-interfered SSs
    - Interference-avoidance zone for interfered SSs
  - Other advanced techniques
    - Power reducing
      - Reduce Tx power at certain time period
      - SS measurement
        - » Through the report from SS, the BS can suggest the value of power reduction of another BS.

Interference-avoidance zone

- Similar to AAS zone



Interference-avoidance zone with staggered first burst



*In this mechanism, we assume that all coexisting BSs can stagger the first burst to each other. Thus there is no need of duplicated DL/UL-MAP.

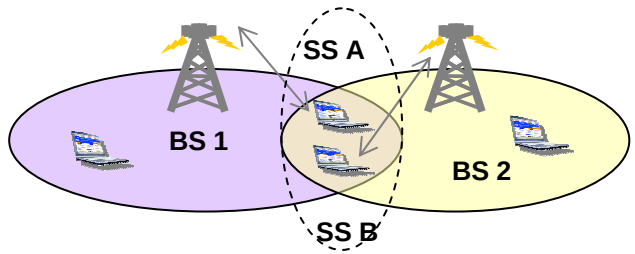
Frame on-off with BSs join scheduling (1)

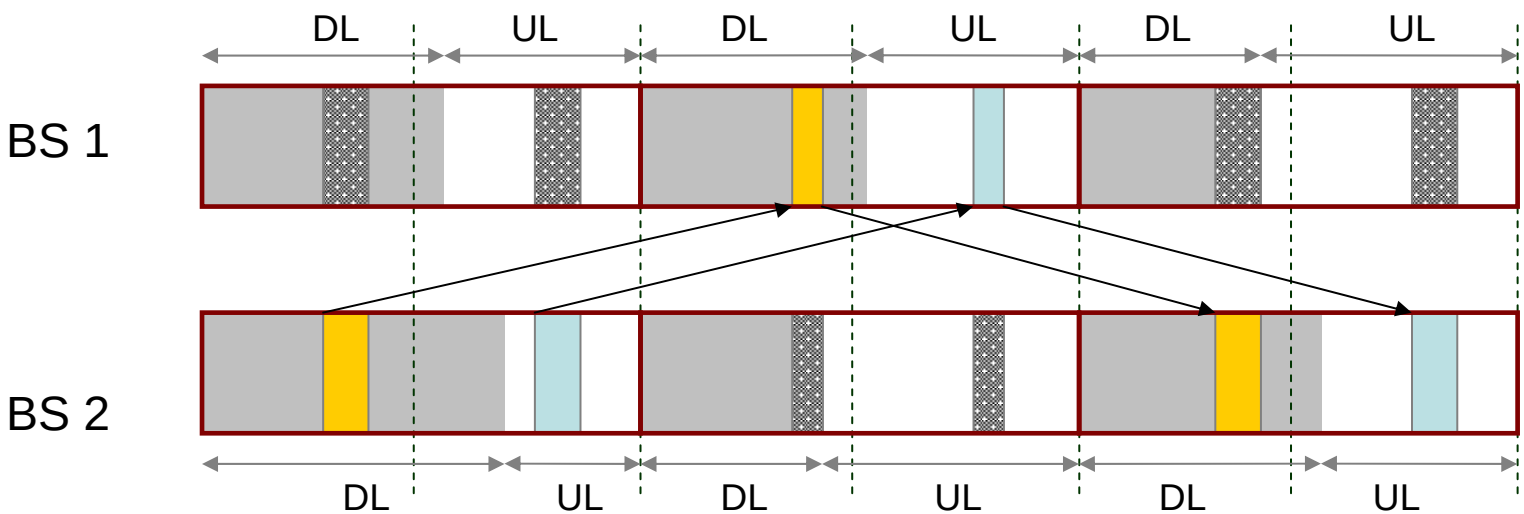
- The same frame duration *case 1* – frames are turned off partially

UL interference-avoidance zone: the STs that may interfere neighbor BS shall only send data in this zone.

DL interference-avoidance zone: the STs that may be interfered by neighbor BS shall only receive data in this zone.

Turn off





Pseudo DL/UL boundary

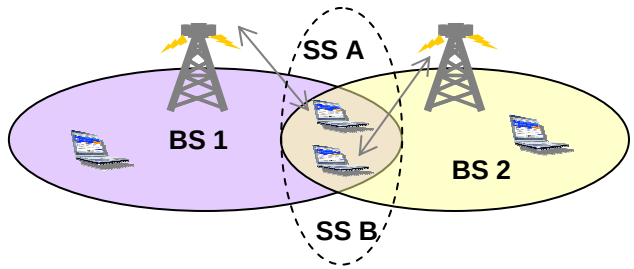
Frame on-off with BSs join scheduling (2)

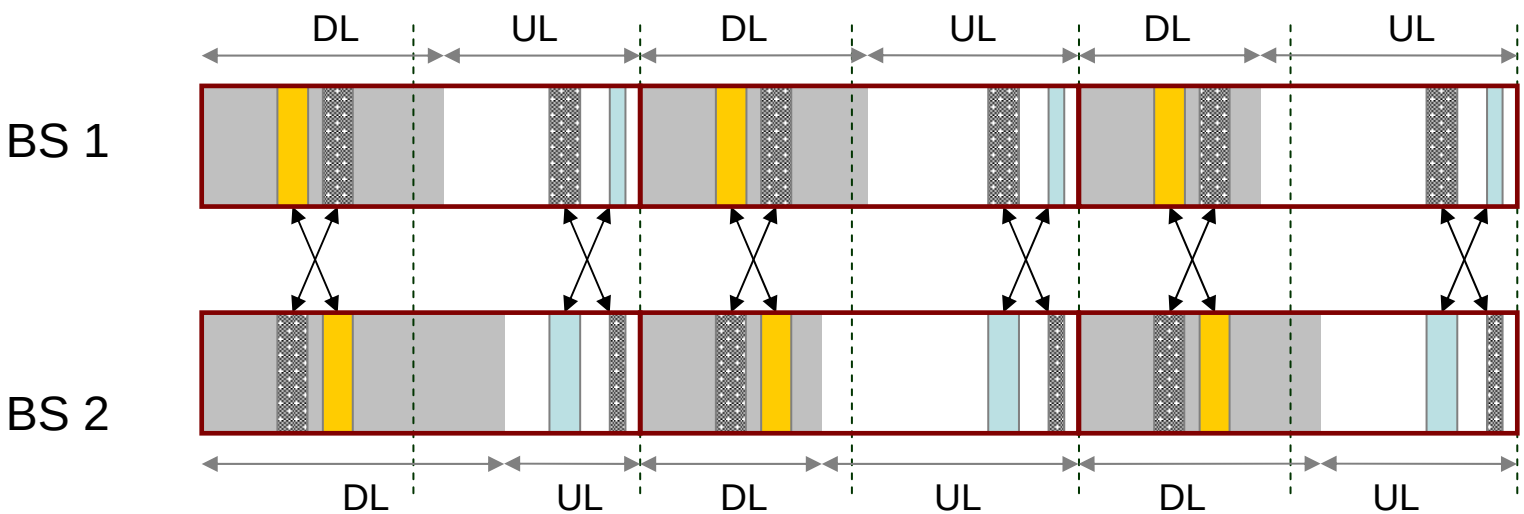
- The same frame duration *case 2* – frames are turned off partially

UL interference-avoidance zone: the STs that may interfere neighbor BS shall only send data in this zone.

DL interference-avoidance zone: the STs that may be interfered by neighbor BS shall only receive data in this zone.

Turn off





Frame on-off with BSs join scheduling (3)

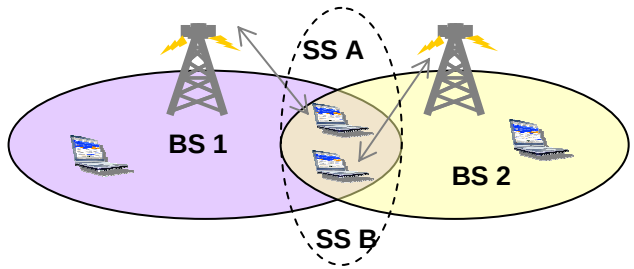
- The same frame duration *case 3*
  - Instead of turning off, the BS can ***reduce Tx power in DL*** or **exclude the STs in the overlapping coverage in UL**

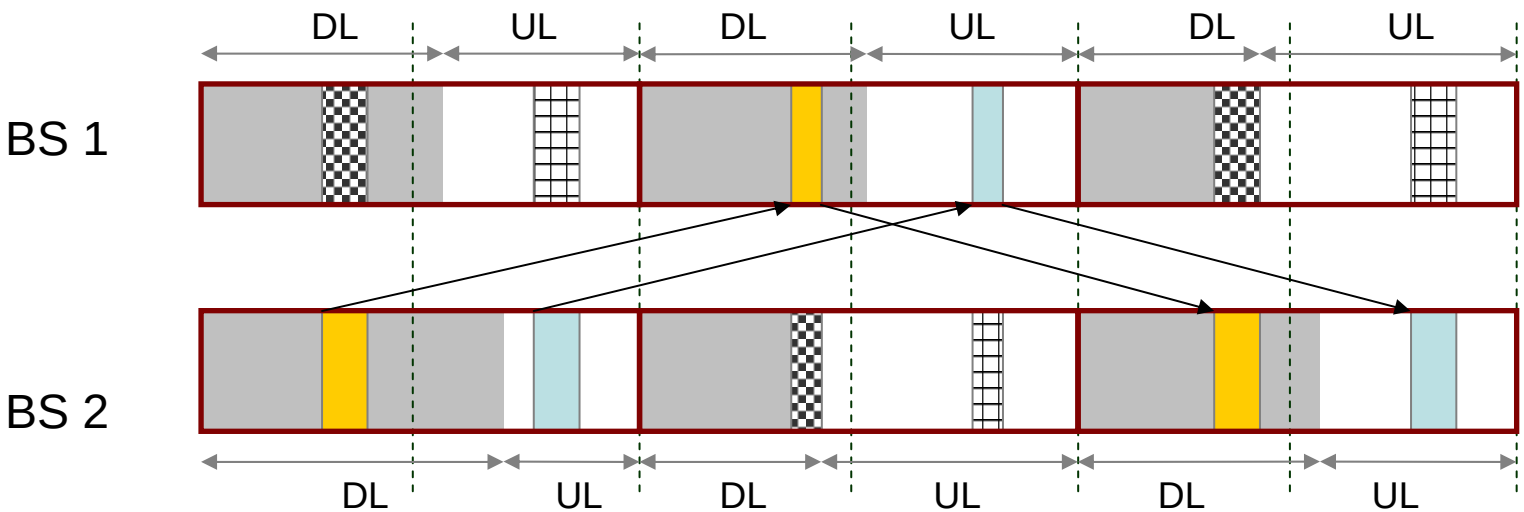
UL interference-avoidance zone: the STs that may interfere neighbor BS shall only send data in this zone.

DL interference-avoidance zone: the STs that may be interfered by neighbor BS shall only receive data in this zone.

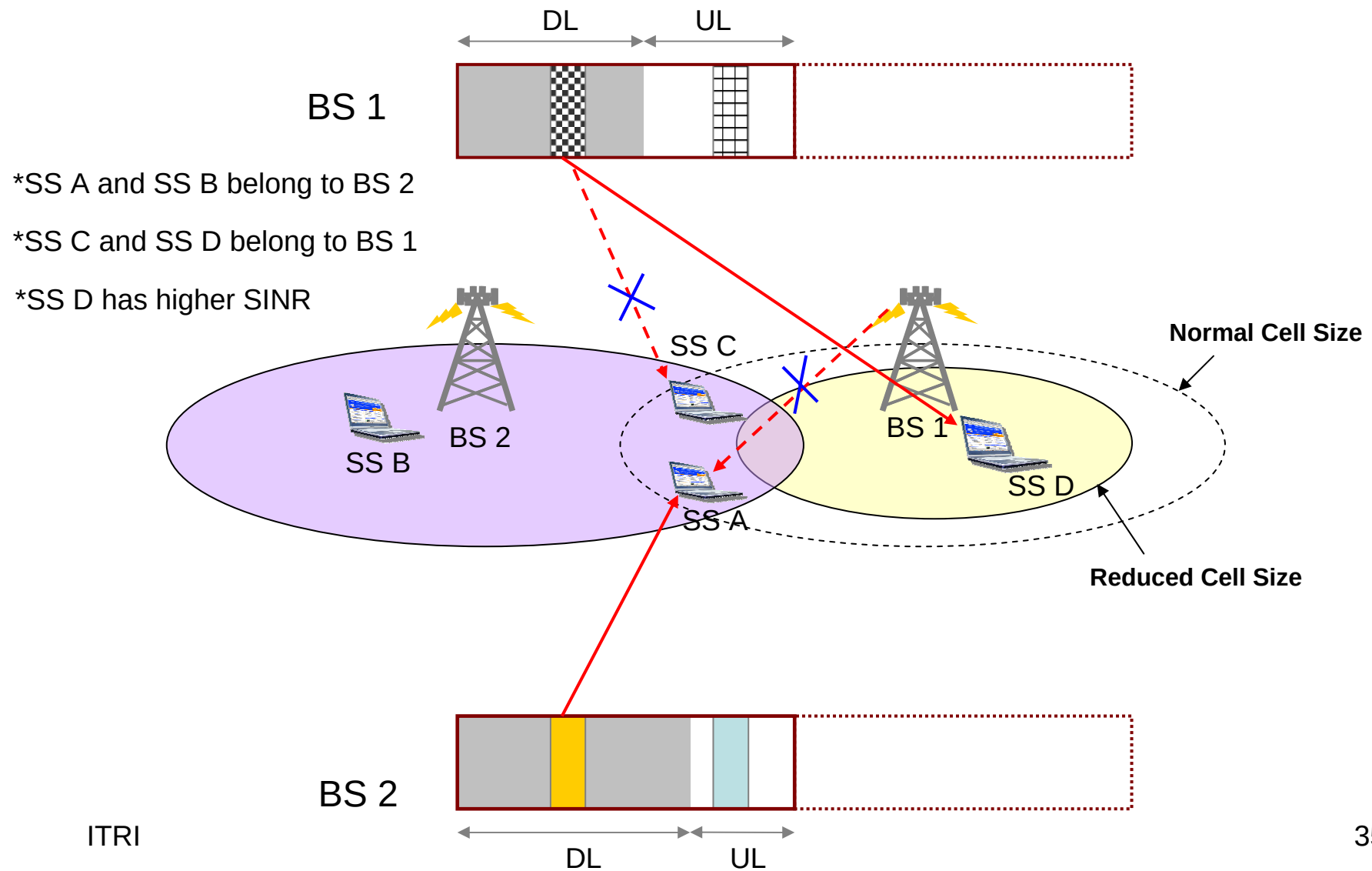
Reduce Tx power

Exclude the interfering STs

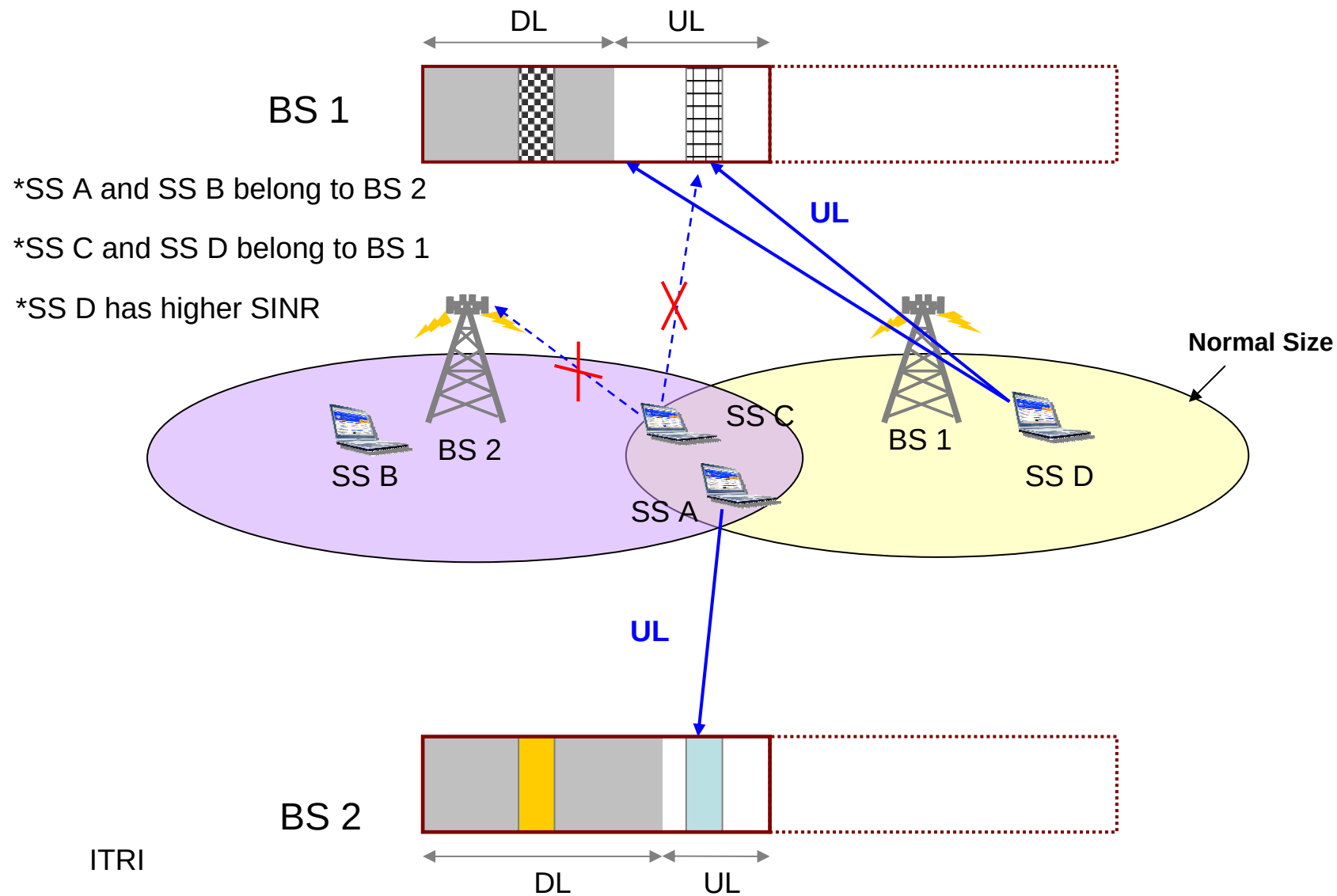




Frame on-off with BSs join scheduling - reduce Tx power



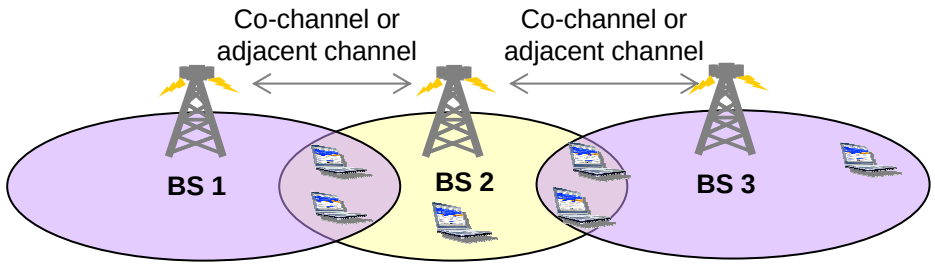
Frame on-off with BSs join scheduling - exclude the interfering STs

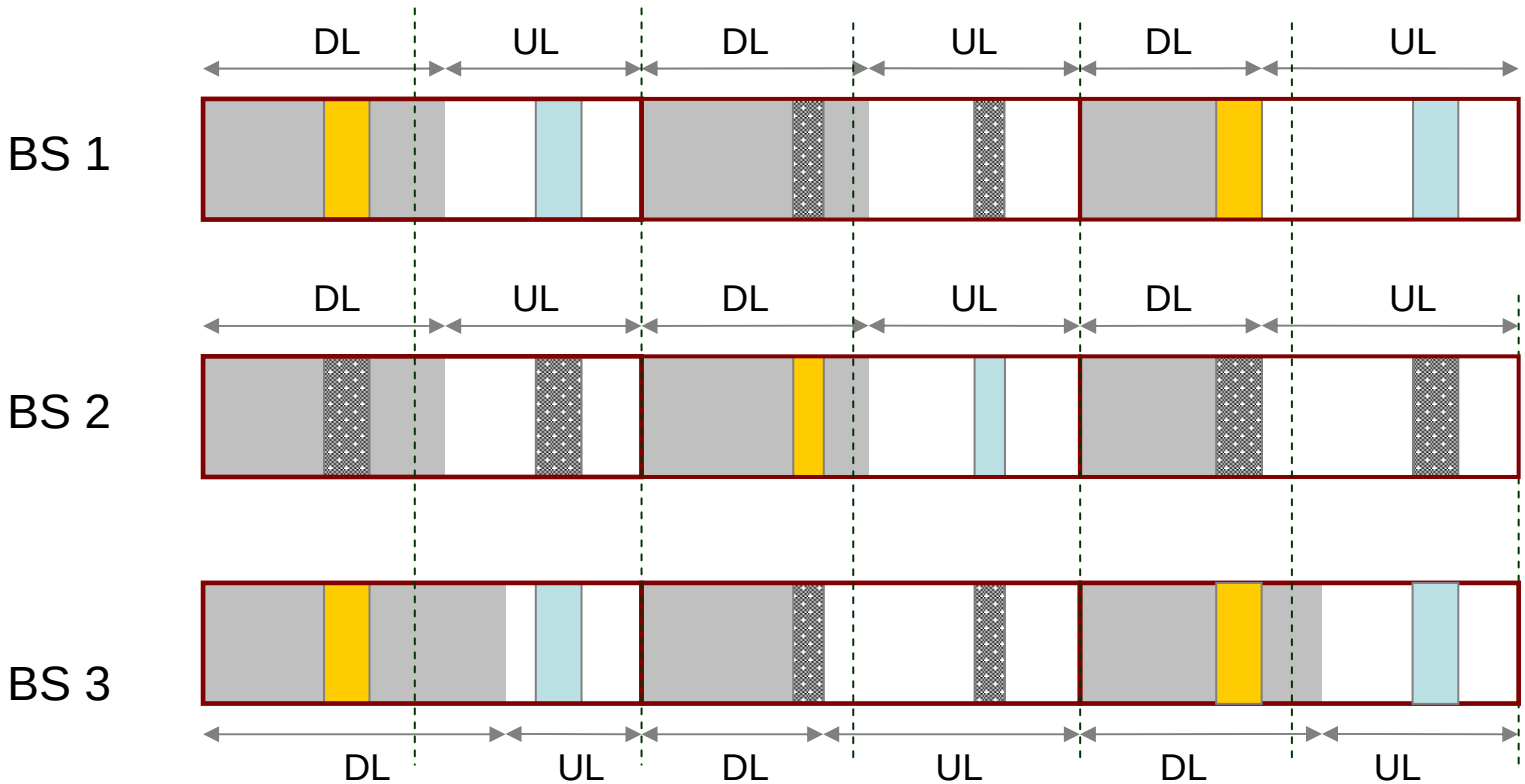


Frame on-off with BSs join scheduling – multiple BSs (4)

*BS 2 suffers the adjacent channel or co-channel interference from BS1 and BS 3

*In this case, BS 2 coordinates the BSs join scheduling





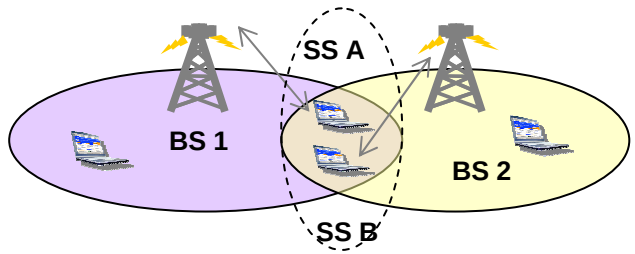
Frame on-off with BSs join scheduling (4)

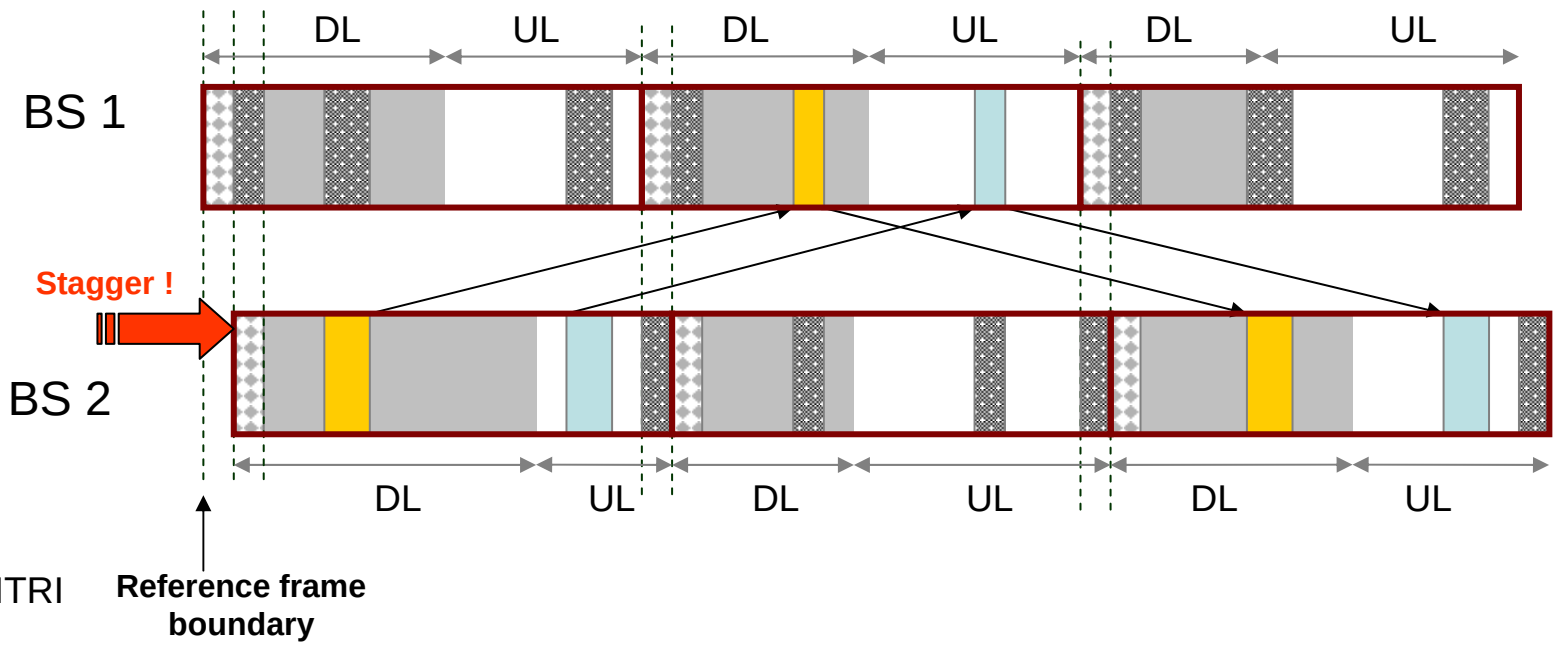
- The same frame duration and *stagger the first bursts* of two coexisting BSs

UL interference-avoidance zone: the STs that may interfere neighbor BS shall only send data in this zone.

DL interference-avoidance zone: the STs that may be interfered by neighbor BS shall only receive data in this zone.

Turn off or Tx reduce power in DL or limited usage in UL





Summary

- This contribution evaluates the techniques used to facilitate the co-channel and adjacent channel coexistence in 802.16 LE.
- The proposed techniques can
  - Improve the system performance through reducing the adjacent channel interference by join scheduling.
  - Improve the license-exempt band utilization as the co-channel and adjacent channel can coexist.
  - Improve the deployment flexibility since it provides another choice besides DSC/DSF.
- The join scheduling or Share RRM algorithm is needed.

Other advanced techniques

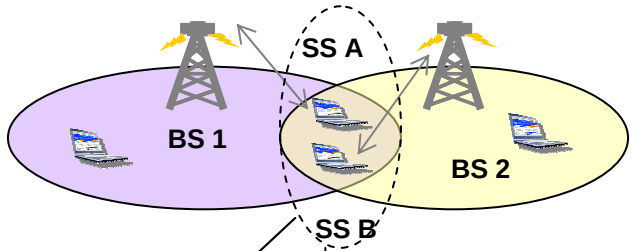
- DL/UL interleaving with BSs join scheduling
- Subchannel splitting with BSs join scheduling

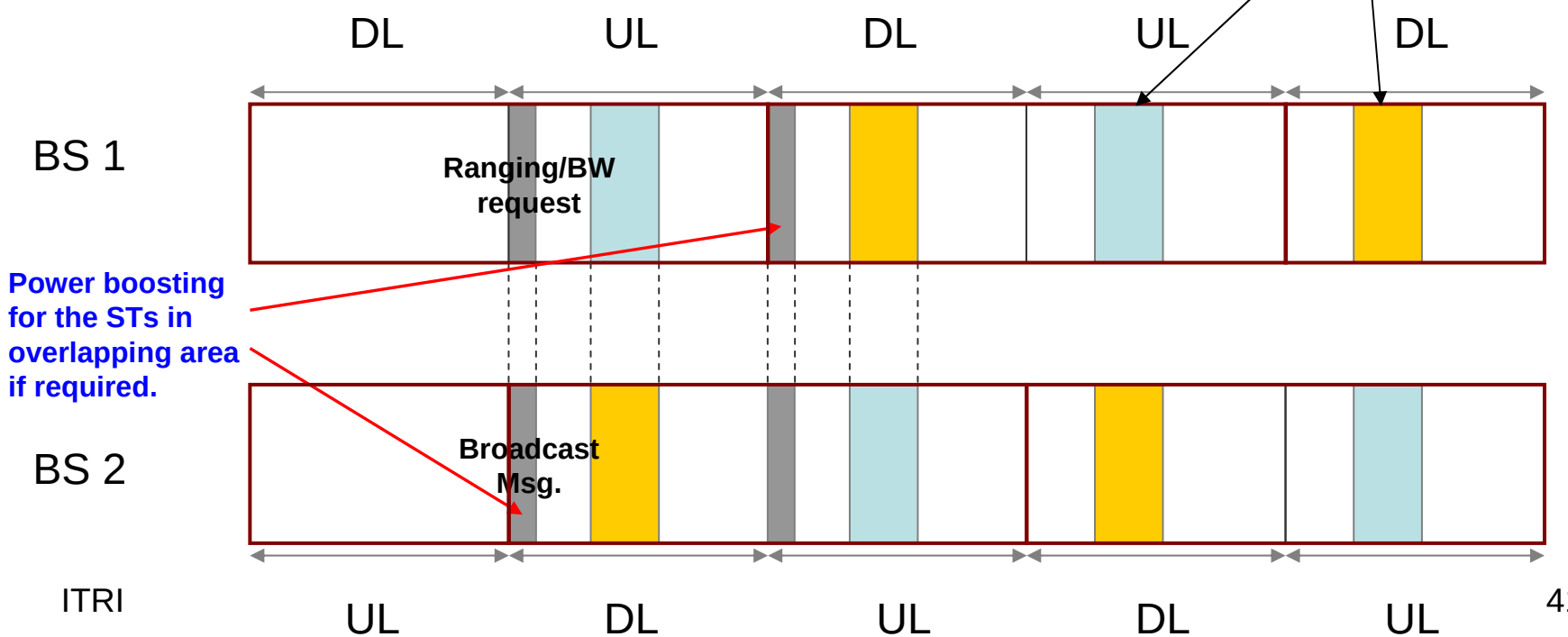
DL/UL interleaving with BSs join scheduling

- Same frame duration and DL and UL intervals are equal (DL=UL)

UL interference-avoidance zone: the STs that may interfere those STs from neighbor BS shall only send data in this zone.

DL interference-avoidance zone : the STs that may be interfered by those STs from neighbor BS shall not receive data in this zone.



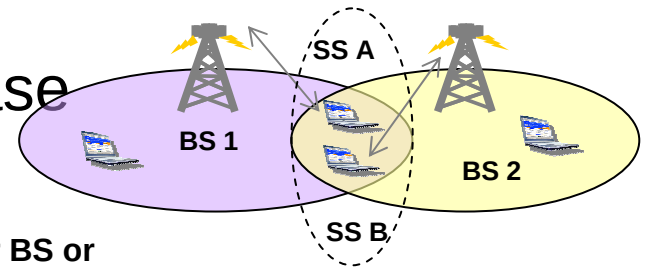


Discussion

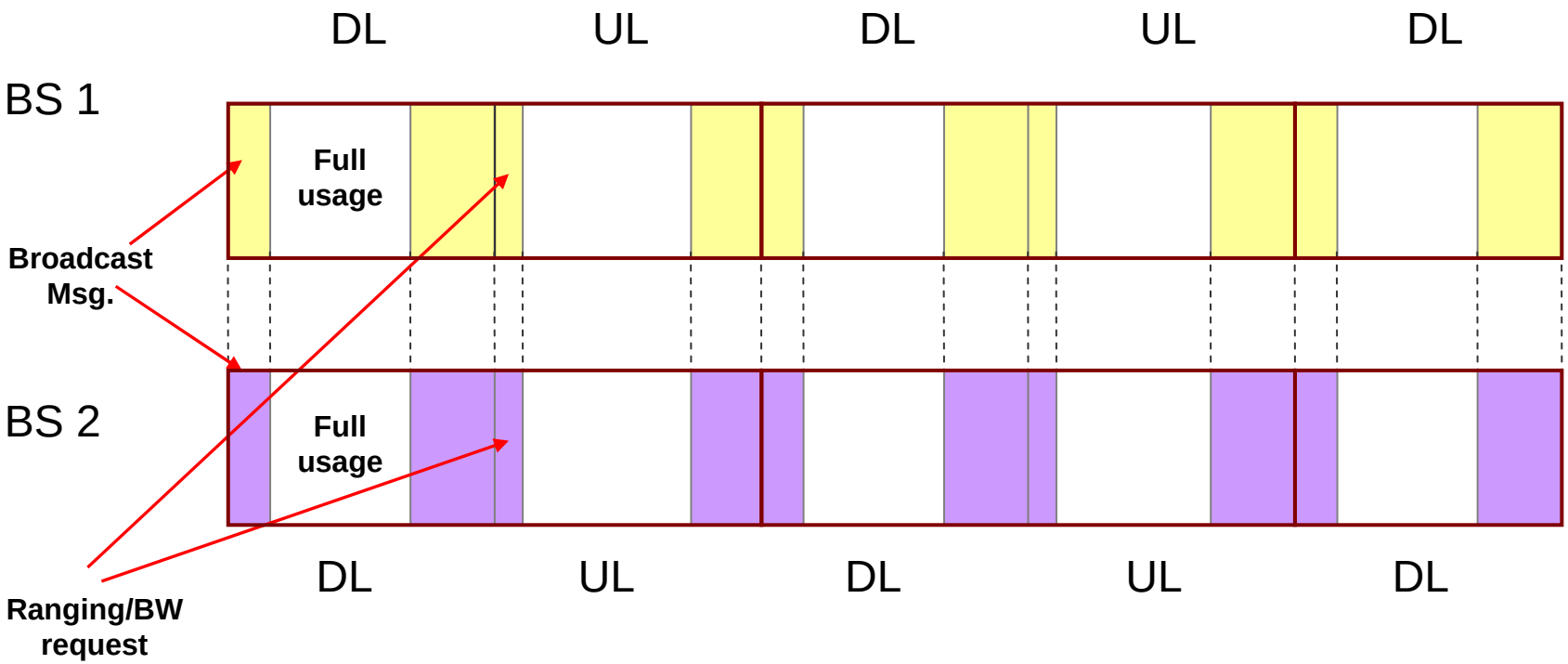
- DL/UL interleaving with BSs join scheduling
  - Solve the ST to ST interference.
  - While DL and UL intervals are equal, this method is quite simple.
  - The BS need only negotiate two zones in DL subframe and UL subframe, separately.
  - While the DL and UL intervals are ***not*** equal, the complexity of this method may increase.

Subchannel splitting with BSs join scheduling (1)

- Example of the same frame duration case



interference-avoidance zone: the STs that may interfere neighbor BS or interfered by neighbor BS shall only send/receive data in this zone.

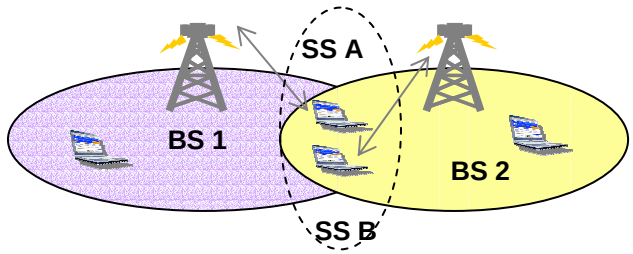


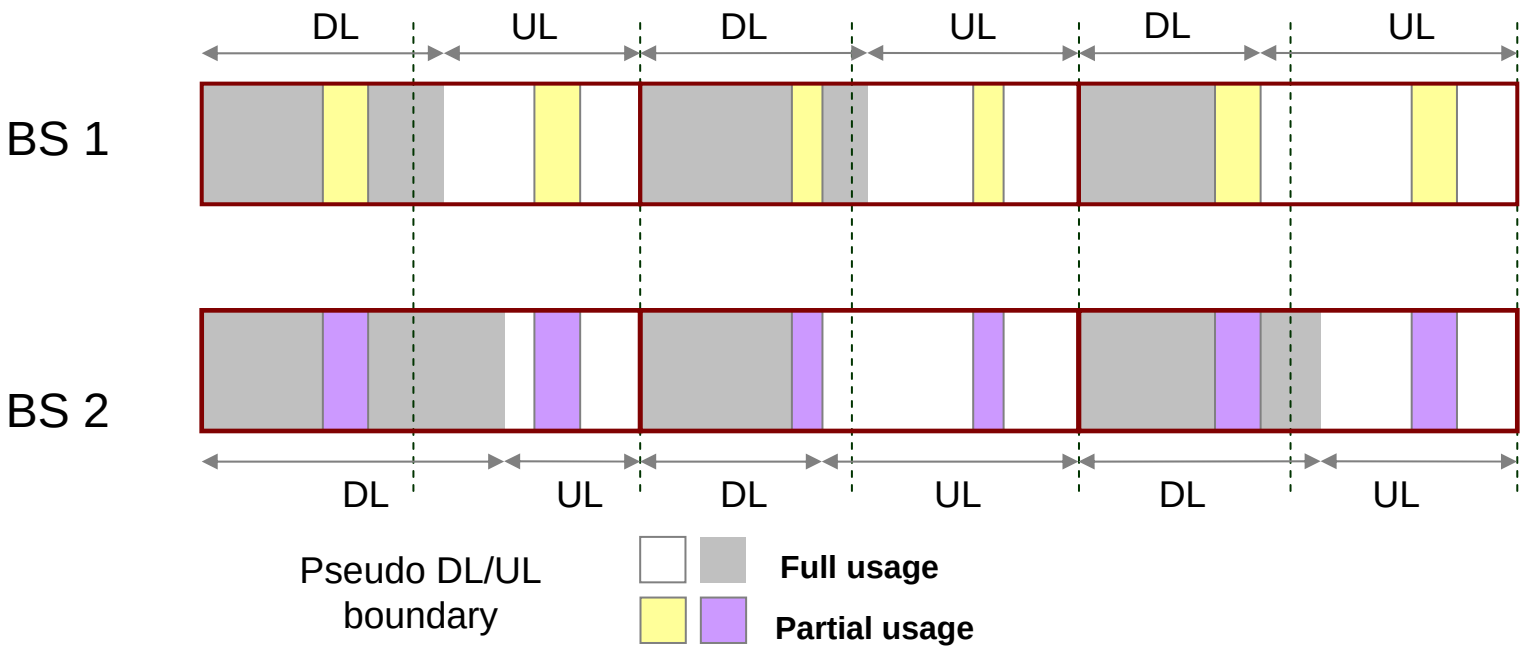
Full usage Partial usage

Subchannel splitting with BSs join scheduling (2)

- Same frame duration case example

interference-avoidance zone: the STs that may interfere neighbor BS or interfered by neighbor BS shall only send/receive data in this zone.





References

1. IEEE C802.16d-04/30, “Spectrum sharing in License Exempt bands – protocol proposal”.
2. http://www.cdg.org/technology/3g/advantages_cdma2000.asp