Sub-frame based Multi-Radio Coexistence Control Mechanism for IEEE 802.16m

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Source: Chi-Chen Lee, Li-Chun Ko, Kyle Hsu, I-Kang Fu, Chih-Hao Yeh, Jiun-Jang Su

chichen.lee@mediatek.com, IK.Fu@mediatek.com

MediaTek Inc.
No.1, Dusing Rd. 1, Hsinchu Science-Based Industrial Park,
Hsinchu, Taiwan 300, R.O.C.

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Base Contribution: N/A

Purpose: To be discussed and adopted by TGm for the P802.16m SDD

Outline

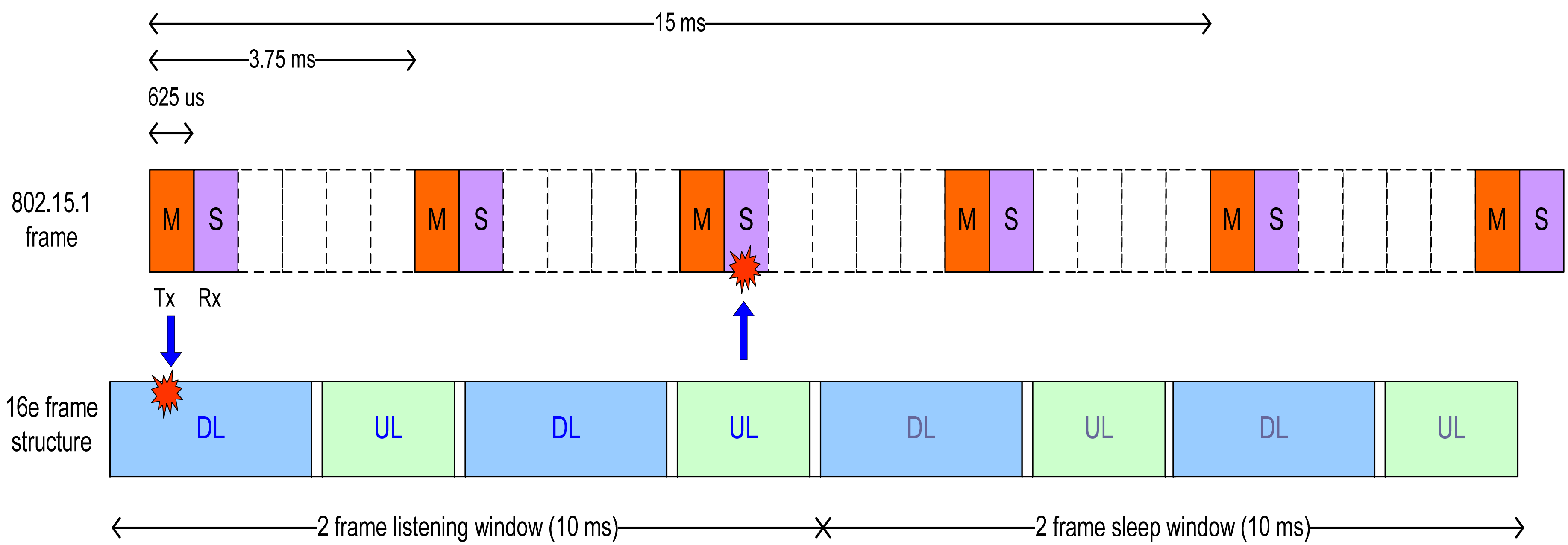
- Problems in Mechanism defined in IEEE 802.16 Rev2
- Proposed Multi-Radio Coexistence Control Mechanism
- Text Proposal

Problems in Mechanism defined in IEEE 802.16 Rev2

- **Problems #1 in the mechanism defined in current mechanism in IEEE 802.16 Rev2**

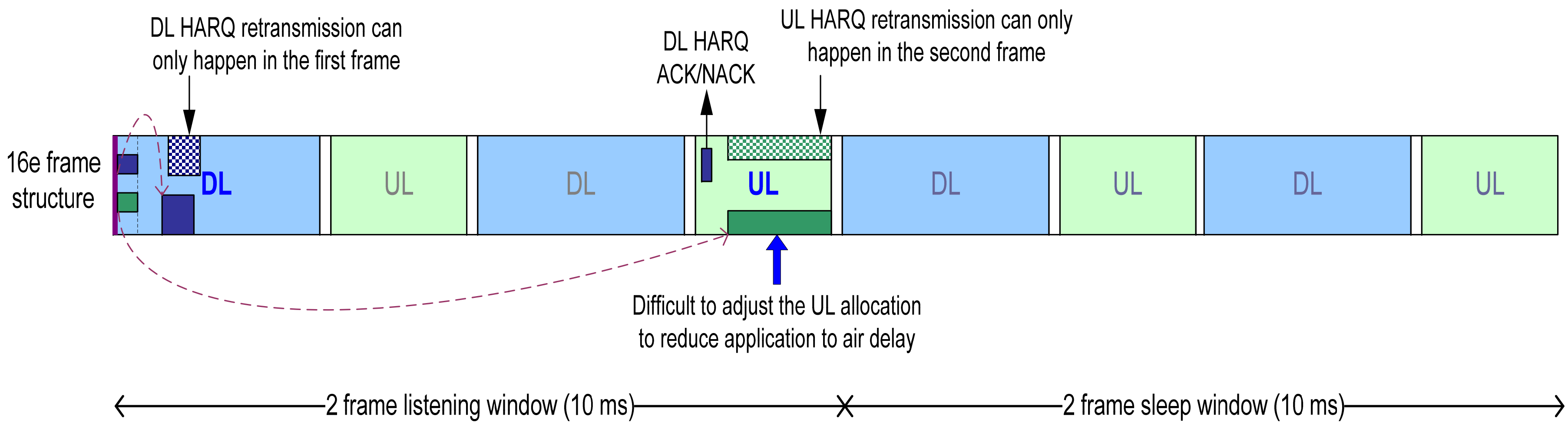
  Consider an example for co-located coexistence mode 2 defined in [1]

  - Scenario: 802.16 + 802.15.1 VoIP call
  - Listening window and sleep window are both 2 frames
    - BS should provide any DL allocation as much as possible in the first frame of listening interval
      - 802.15.1 transmission in the first fame of listening interval may still interfere the 802.16 reception.
    - BS shall not provide any MS UL allocation in the first frame of the listening interval
      - 802.16 transmission may still interfere the 802.15.1 reception in the second fame of listening interval.



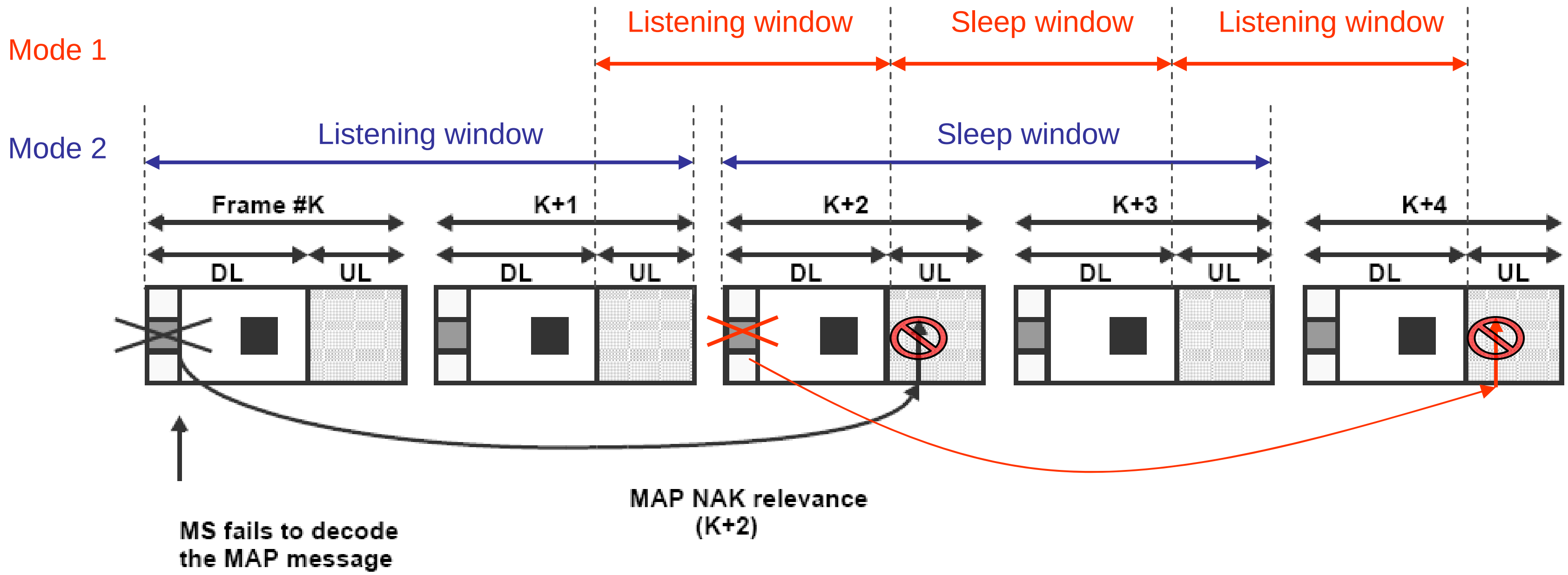
Problems in Mechanism defined in IEEE 802.16 Rev2

- Enable co-located coexistence mode 2 is the only choice
- More constraint on BS scheduling especially for HARQ retransmission
  - Based on the constraint: “The BS should populate the DL subframe the way that DL allocations for all MS with active Co-located-Coexistence- Enabled PSCs precede in time the allocations for other MS.”
  - DL HARQ retransmission can only be sent in first frame of the listening interval and UL HARQ retransmission can only be sent in the second frame of the listening interval .
- More delay
  - For HARQ retransmission, 5-10 ms extra delay in DL, 10 ms extra delay in UL
  - Difficult to adjust UL allocation occasion to further reduce the transmission delay once the MS enters sleep mode. This increase queuing delay at MAC layer.



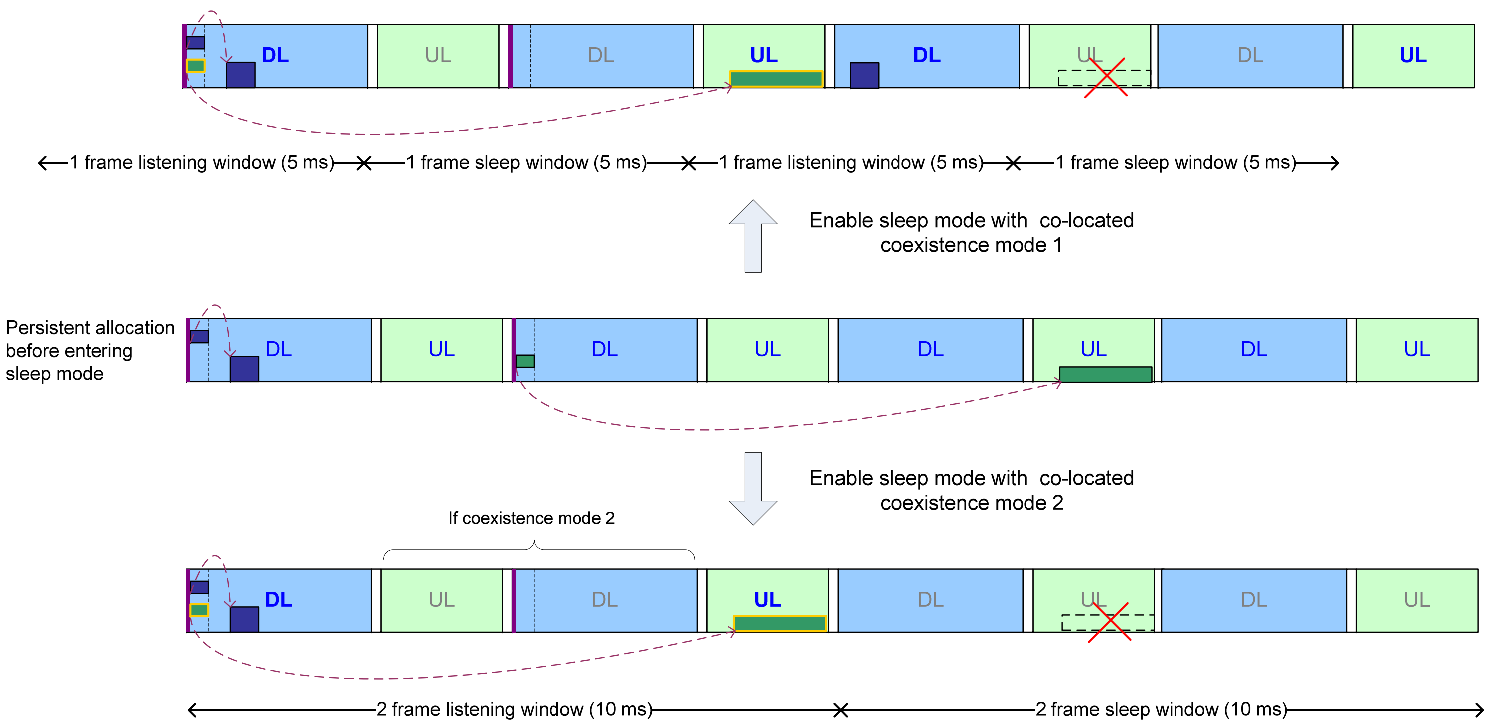
Problems in Mechanism defined in IEEE 802.16 Rev2

- **Problems #2 in the mechanism defined in IEEE 802.16 Rev2**
  - Problem on persistence allocation issue considering active co-located coexistence radio
  - MAP NAK design cannot work with current Rev2 co-located coexistence design.



Problems in Mechanism defined in IEEE 802.16 Rev2

- BS needs to de-allocate and re-allocate persistent allocation unnecessarily once co-located coexistence radio at the MS is activated.
  - E.g. user starts to use 802.15.1 during VoIP call
  - Note: BS may also need to adjust persistence allocation for normal sleep mode based on the power saving class pattern.



Problems in Mechanism defined in IEEE 802.16 Rev2

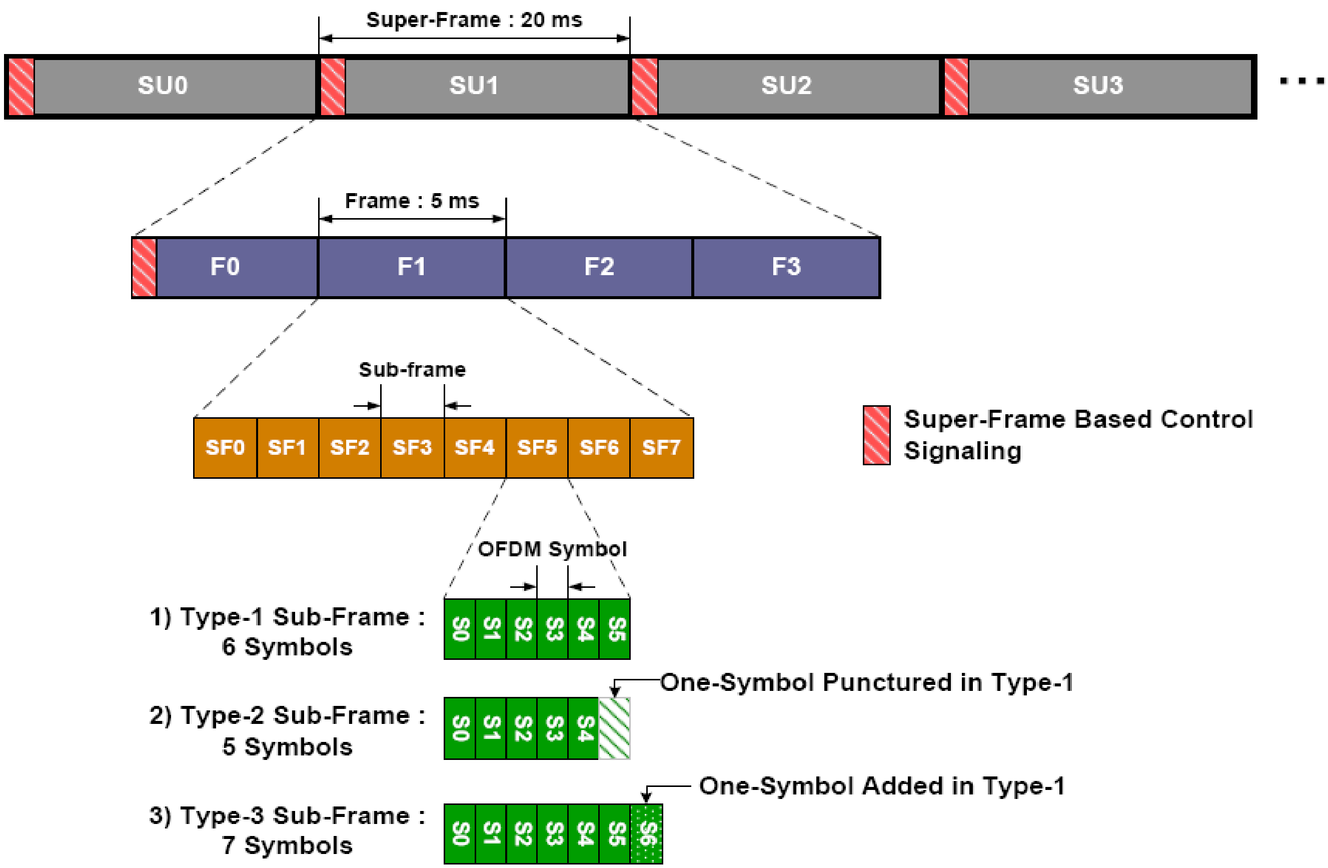
Required improvement for the mechanism defined in IEEE 802.16 Rev2

- **Efficiency**
  - Fame level granularity is not enough. Finer granularity, e.g. less than one frame, can improve the overall radio performance by increasing the time domain utilization.
  - Co-located coexistence radio characteristics are not available. Some information such as Tx power level, operating frequency and channel bandwidth may be helpful to decide the interference level.
  - Avoid Tx/Rx is the only solution. Through inter-radio interference measurement, some moderate interference can be solved by changing carrier frequency, using more robust MCS (Modulation and Coding Scheme), power boosting, power control and HARQ.
    - MS can measure the interference level, e.g. using effective CINR, of potential collision duration and report to BS, let BS decide whether or not to allocate DL burst during the potential collision duration.
  - More delay on HARQ retransmission and more queueing delay at MAC
  - Unnecessarily de-allocate and re-allocate the persistent allocation when enter sleep mode
- **Flexibility**
  - MS must enter sleep mode to enable co-located coexistence radio
    - MS may not need to enter sleep mode for Wireless Gateway scenario
  - Strong restriction at BS, BS can only accept MS request.
- **Scalability**
  - Difficult to extend the current design to support new technology and multiple active co-located coexisting radio.
- **Compatibility**
  - normal power save operation is disabled when PSC is used for co-located coexistence radio.
  - MAP NACK channel design conflicts with current co-located coexistence mode 1 and mode 2.

- Problems in Mechanism defined in IEEE 802.16 Rev2
- Proposed Multi-Radio Coexistence Control Mechanism
- Text Proposal

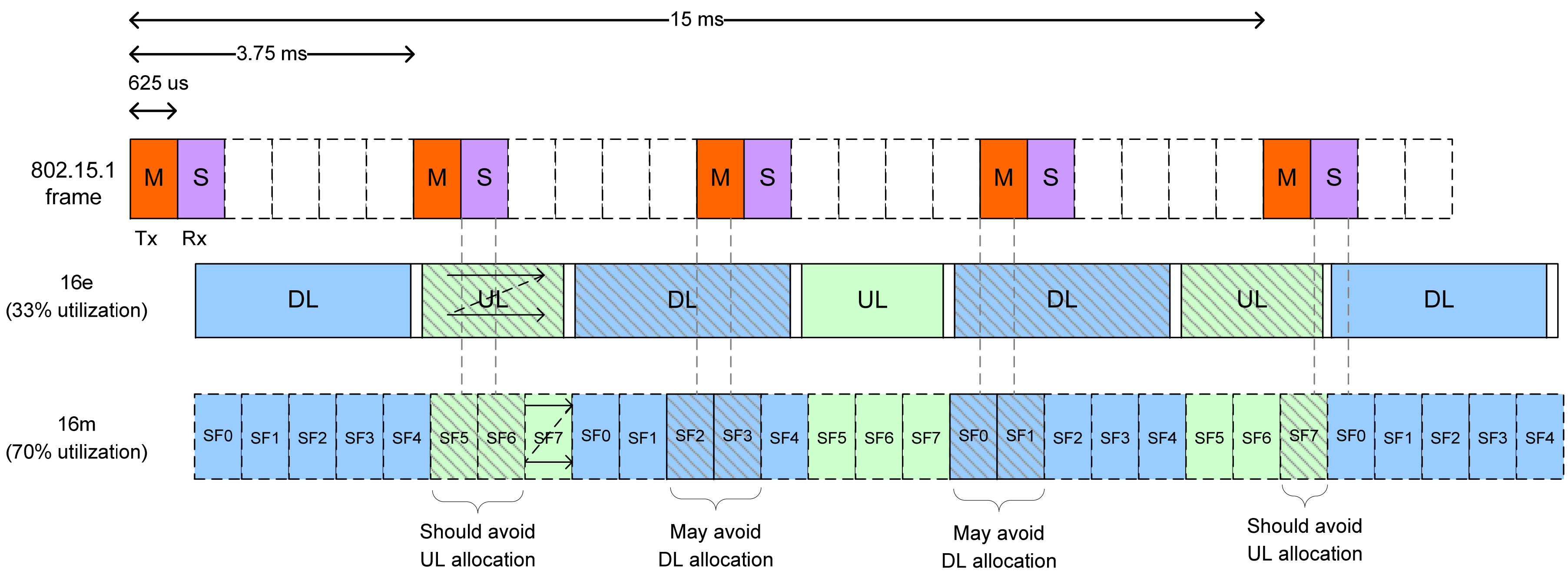
Proposed Multi-Radio Coexistence Control Mechanism

- Instead of using the frame-based sleep mode control defined in IEEE 802.16 Rev2 standard, this contribution proposes to use "sub-frame" based scheduling technique to achieve finer control resolution.
  - Sub-frame has been defined in P802.16m SDD with smaller time duration



Proposed Multi-Radio Coexistence Control Mechanism

- Compare the efficiency with the legacy mechanism proposed in 802.16 Rev2
  - Utilization can be improved if MS can provide fine granularity of the co-located coexistence radio activities



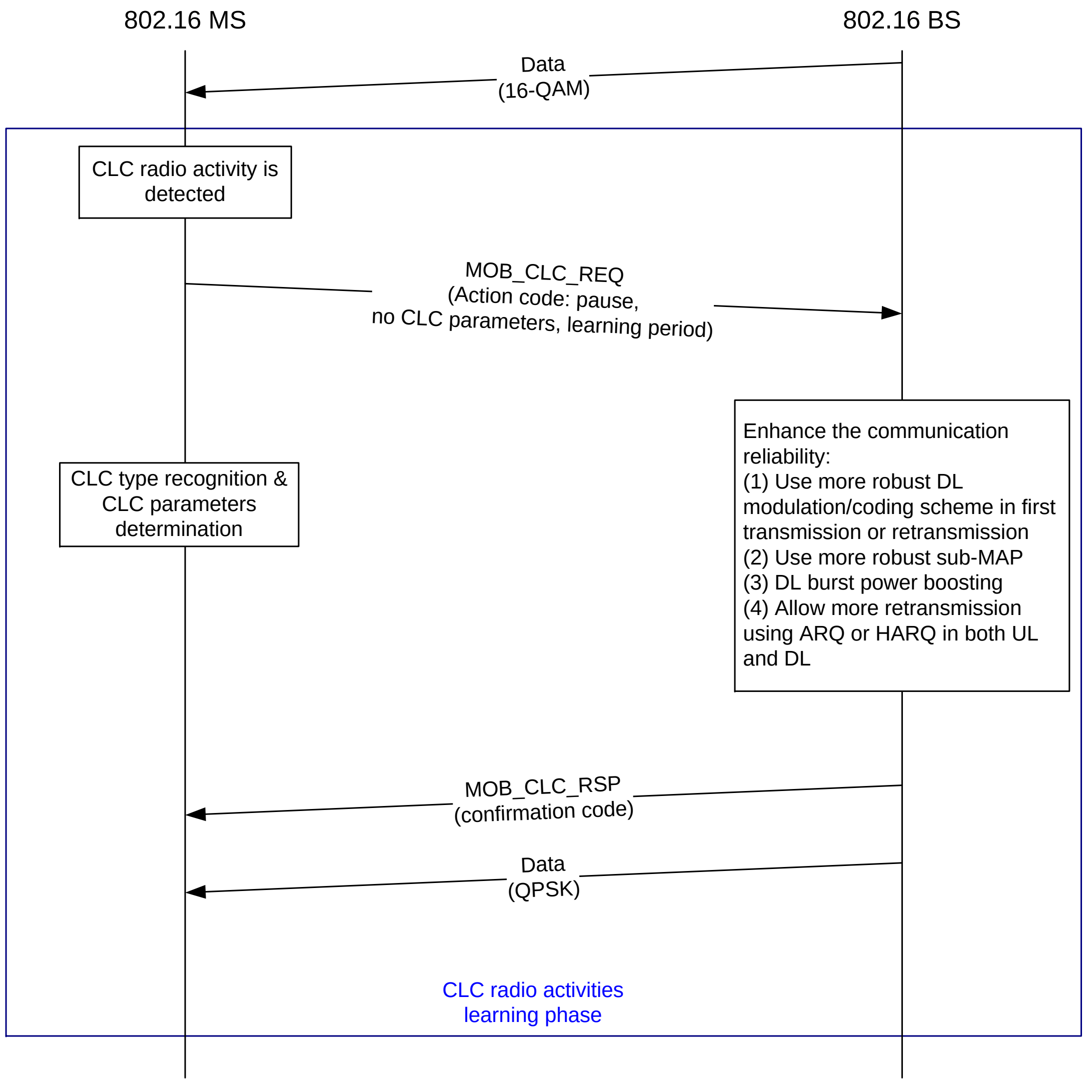
Proposed Multi-Radio Coexistence Control Mechanism

- CLC (Co-Located Coexistence) radio initialization sequence
  1. When 802.16 MS is activated after other CLC radios
     - PTA (block other radio) plays an important role in this case.
  2. When other CLC radio is activated after 802.16 MS
     - Air interface need connection set up time for later activated CLC radios
- For case 2, MS may need some time to learn the CLC radio characteristics such as Tx power, Rx sensitivity and traffic pattern.
- Thus, there are two phases to enable CLC radio operation
  - Learning phase
  - Negotiation phase

CLC radio design – learning phase (1)

- In this phase, MS can only know that one CLC radio is activated by user but the characteristics such as Tx power, Rx sensitivity and traffic pattern of the CLC radio are still unknown.
- The MS can send the MOB_CLC-REQ message to indicate that MS is learning CLC radio characteristics and the CLC radio is initiating its connection, e.g. listening to beacon or set up connection.
- During the recognition duration included in the message, the MS and the BS should avoid data transmission during the connection set up period.
- During the recognition duration, if the BS has data to the MS, it should use more robust MCS for DL data, use more robust sub-MAP, apply power boosting or perform re-transmission to ensure the successful DL reception at MS.
- Before recognition duration expired, MS can send another MOB_CLC-REQ to enter negotiation phase or re-start the recognition phase. BS may also send MOB_CLC_RSP msg to request MS to extend the learning phase or exit the learning phase.

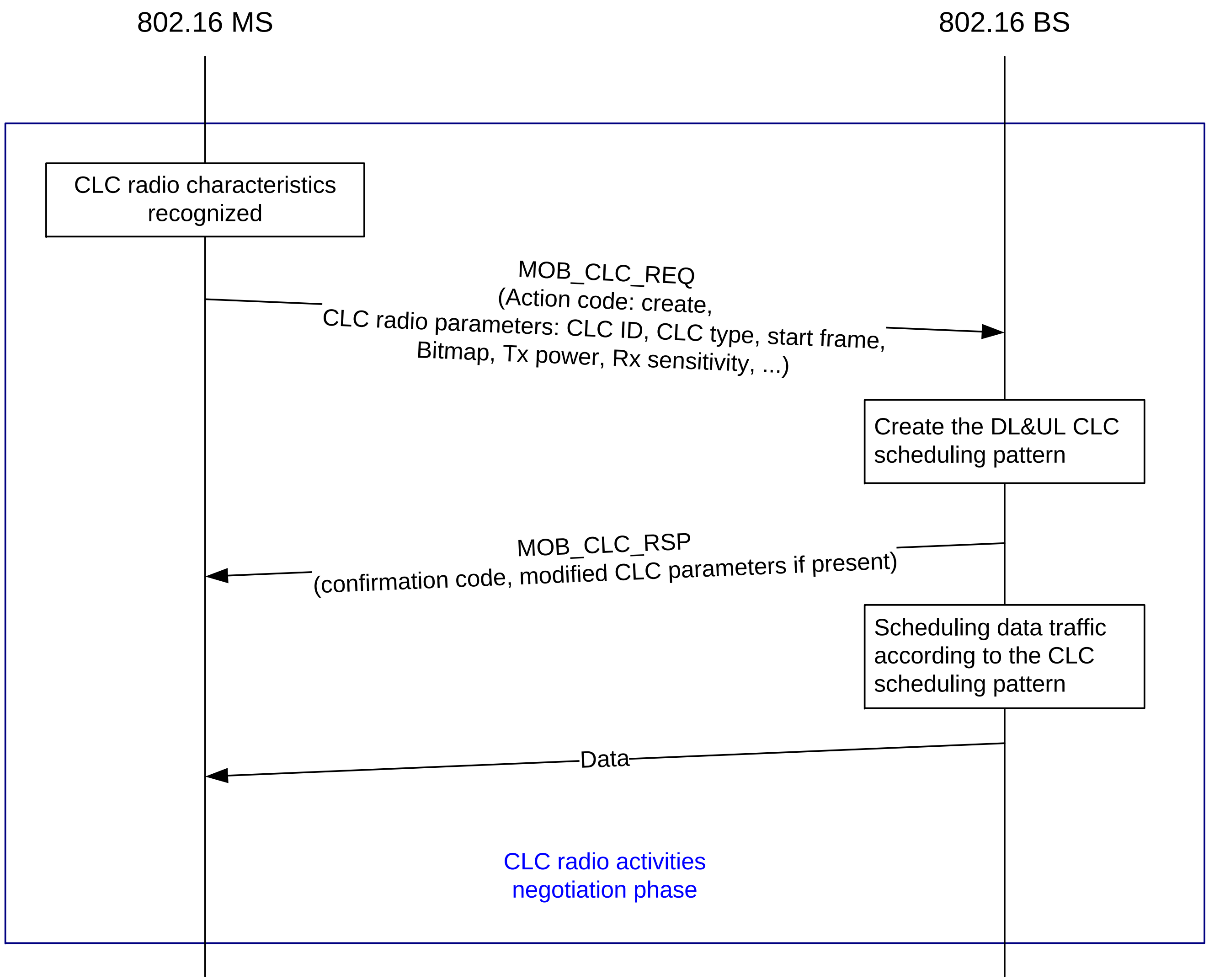
CLC radio design –learning phase (2)



CLC radio design – negotiation phase (1)

- In this phase, CLC radio characteristics are recognized and the MS can send the message (e.g. MOB_CLC-REQ) to describe the CLC radio activity pattern.
- CLC parameters characterizing the CLC radio may include
  - CLC radio ID, CLC radio type, CLC radio parameters take effect start frame, CLC radio traffic pattern, e.g. use subframe bitmap to characterize the CLC radio DL/UL traffic.
- BS will response MS with message (e.g. MOB_CLC-RSP) to indicate the MS whether it accepts or rejects the request from MS.
- BS may modify the CLC radio activity pattern suggested by the MS.
- BS may also update the existing CLC radio activity pattern when BS loading is changed.

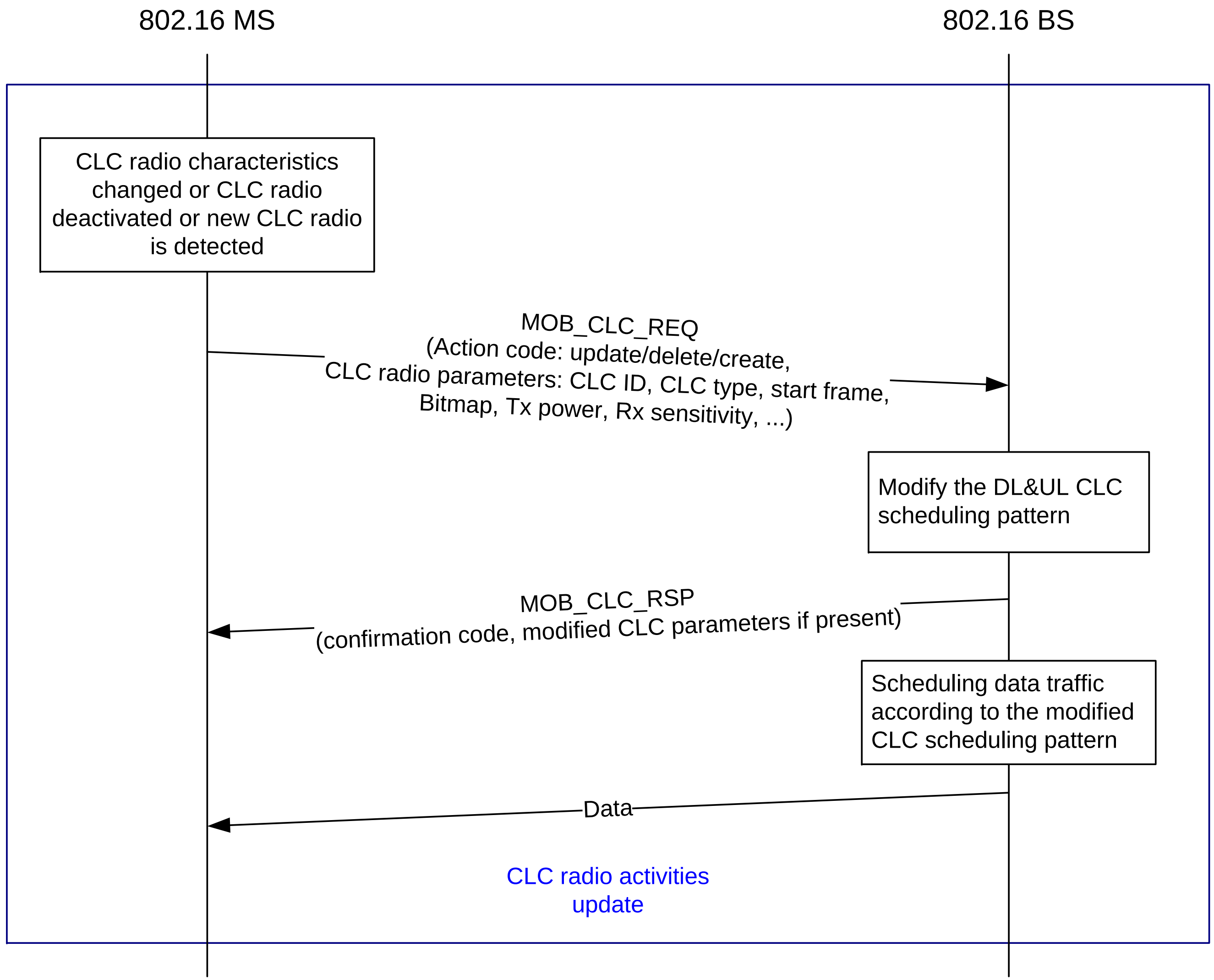
CLC radio design – negotiation phase (2)



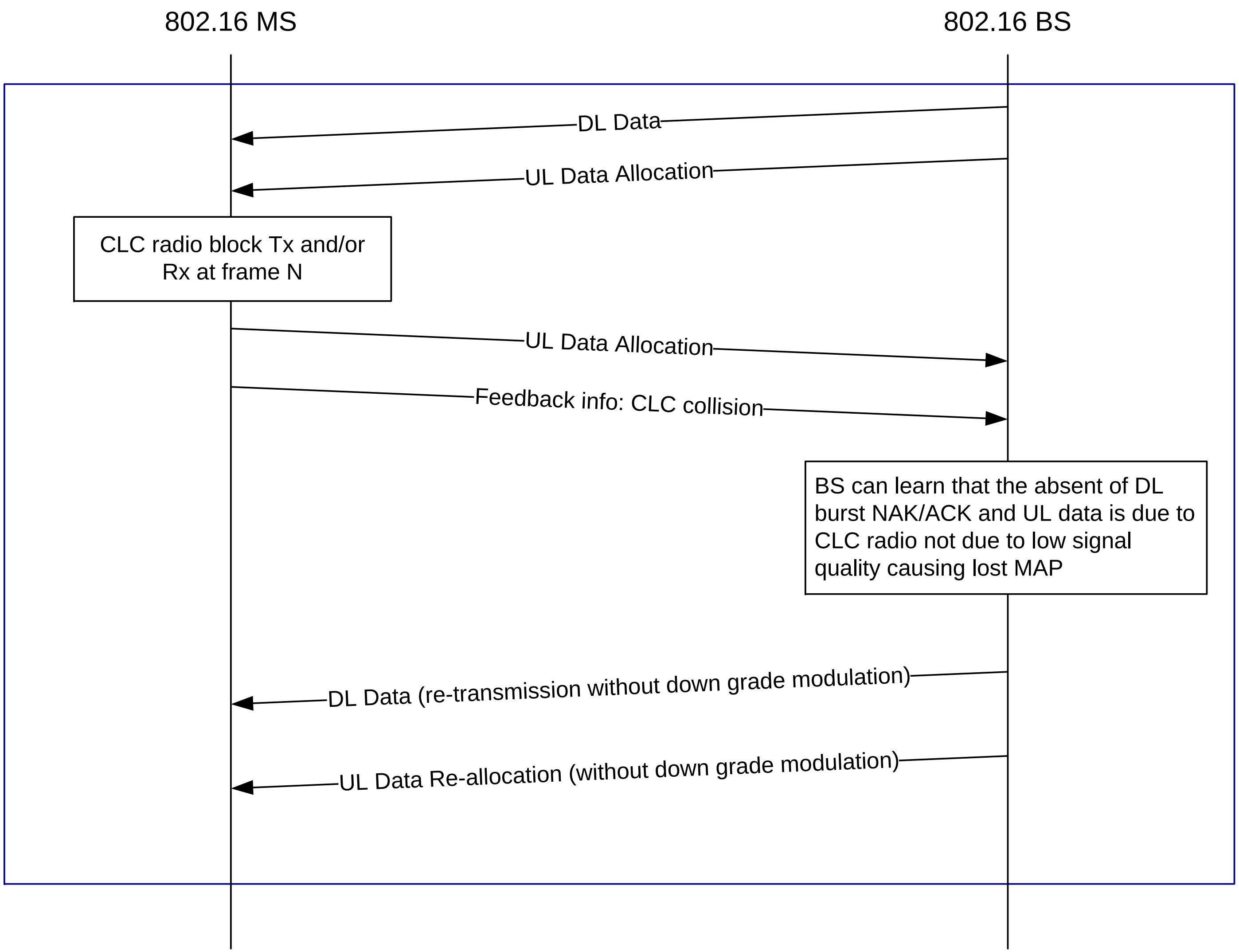
CLC radio design – CLC parameters update/destroy

- After CLC parameters are negotiated between the MS and BS, the MS may update the CLC parameters once the characteristics of CLC radio have changed.
- The BS may update the CLC parameters through message whenever the scheduling capability or loading at BS is changed.
- Once the CLC radio is inactive, the MS can return to normal operation, i.e. no CLC radio, by destroying the CLC parameters.

CLC radio design – CLC update



CLC radio design – CLC collision



CLC radio design – measurement

- Channel measurement
  - When MS performs channel measurement it may discard the polluted measurement result when it detects that CLC radio performs Tx during the measurement duration.
  - BS may command MS not to perform measurement for link adoption during the CLC radio transmission period or BS may command MS to perform measurement during the CLC radio transmission period for estimating the interference from the CLC radio.
- Neighbor scanning
  - MS may avoid to perform neighbor scanning during the Tx duration of the CLC radio.
  - The MS and the BS may negotiated a period of unavailable interval based on the negotiated CLC parameters. The unavailable interval should not overlap with the CLC collision time. Thus MS can perform neighbor scanning without interference from the CLC radio.

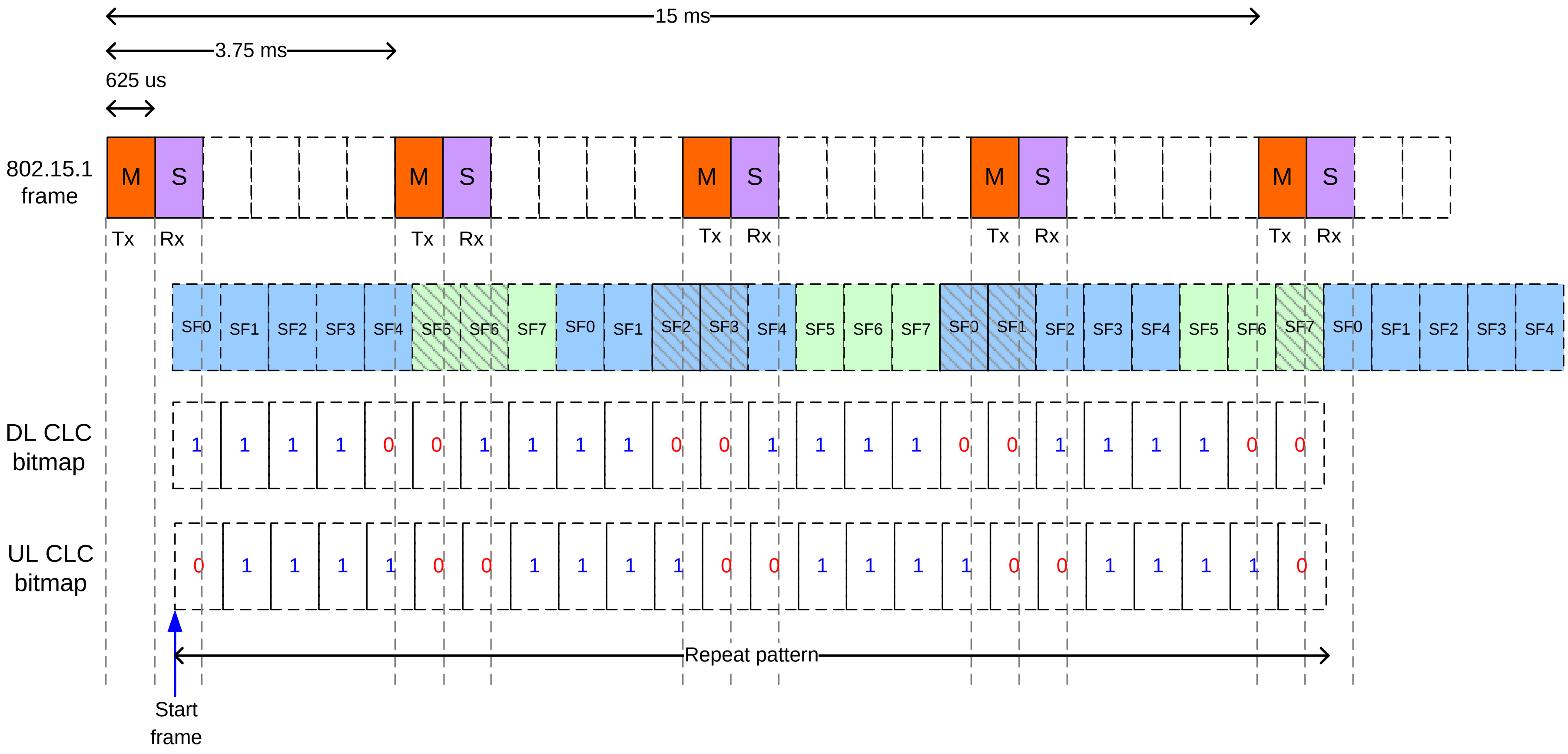
CLC radio design – CLC parameters

- Ways to describe the CLC radio activities
  - CLC radio activity timing information (raw data)
    - E.g. {N, S, P} to describe the CLC traffic starts at frame number N, sub-frame S and periodicity P.
    - It is suitable for CLC radio that has periodicity but requires more calculation at BS.
  - Bitmap
    - E.g. 8 bit for each frame, each bit stands for one sub-frame of the frame.
    - E.g. 1 bit for each frame, 4 bits represent one super-frame.
    - It is suitable for CLC radio that has periodicity, e.g. 802.15.1 SCO/eSCO traffic or 802.11 beacon.
  - Coexistence ratio
    - E.g. in time sharing manner, use percentage, e.g. 30%, of usage time. 802.16 BS may ensure the CLC radio has 30% usage time.
    - This method is suitable for CLC radio without periodicity, e.g. 802.15.1 ACL or 802.11 data.
  - Active window and inactive window
    - E.g. start frame number, CLC radio active duration & inactive duration
      - The window can be in unit of frame, sub-frame or millisecond
  - Real-time (fast) feedback
    - BS may assign a feedback channel or dedicated UL resource (e.g. every 50ms) to let MS report its radio resource preference in the coming frames.
    - This method is suitable for CLC radio with dynamic traffic pattern.

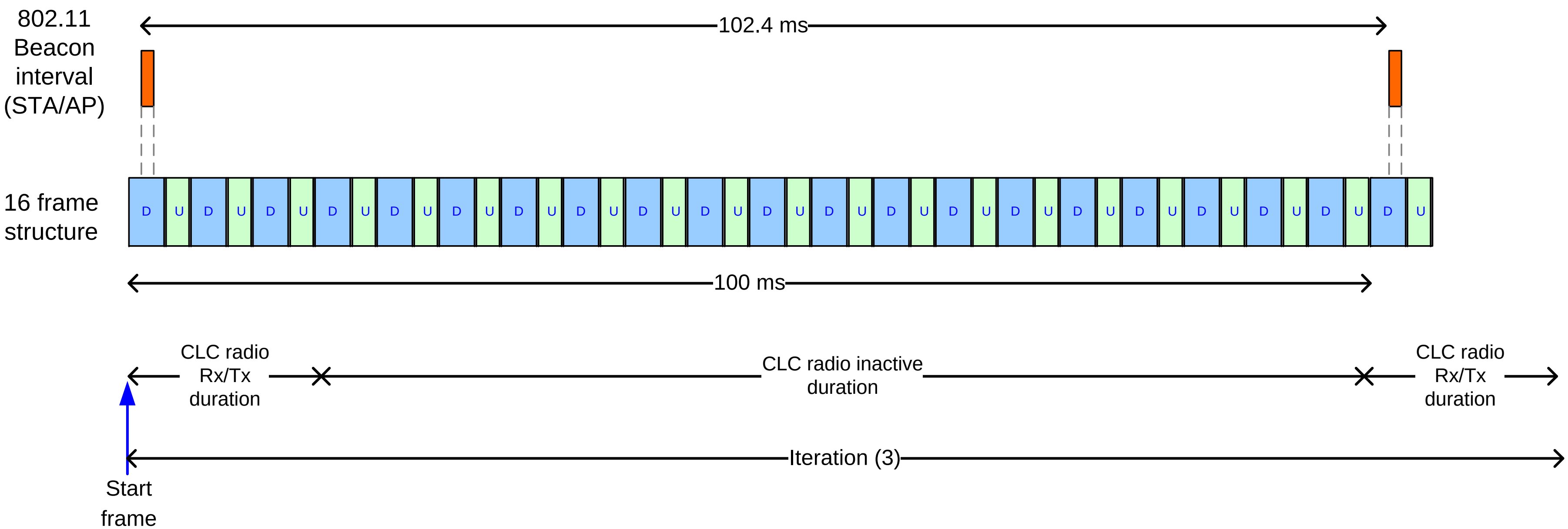
Inter-radio information exchange

- If the CLC radio can obtain the negotiated CLC parameters through inter-radio interface by software or hardware means, CLC radio (802.11 station/AP) may initiated sleep mode during the 802.16 Tx/Rx duration to prevent peer nodes from sending data to the CLC radio during 802.16 Tx duration.

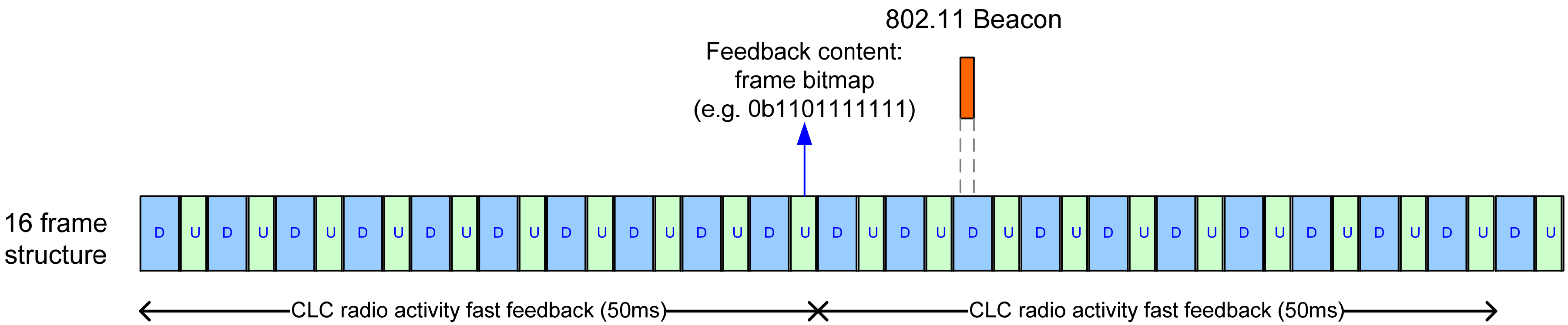
CLC radio design – CLC radio activity description using bitmap



CLC radio design – CLC radio activity description using active and inactive window



CLC radio design – CLC radio activity description using fast feedback



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Text Proposal

[Add the following text into P802.16m SDD]

10.X Multi-Radio Coexistence Control

IEEE 802.16 shall support the multi-radio control mechanism with time resolution in unit of sub-frame.