Signaling Methods to Support Closed-Loop Transmission in 802.16e TDD OFDMA

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Purpose:
Introduce signaling methodology to enable fast, efficient uplink channel sounding to support closed-loop transmission in mobile 802.16e TDD OFDMA systems.

Signaling Methods to Support Closed-Loop Transmission in 802.16e TDD OFDMA PHY

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Contribution 103r2 Summary

- Provides improved support for Closed-Loop transmit antenna techniques in mobile TDD-OFDMA
  - Optional alternative to Feedback for TDD systems
  - Provides much lower channel measurement latency than feedback in TDD systems
  - Important for mobile channels
  - Usable with or without the AAS zone

- Defines a flexible and efficient scheme for the SS to transmit channel sounding waveforms on the UL
  - BS performs simple channel estimation to determine BS-SS channel response (assumes TDD and calibration)
  - SS transmits sounding waveforms only when needed

Closed-Loop Transmit Antenna Arrays

- Exploit knowledge of the Tx-Rx Channel Response
  - Per-carrier coherent beamforming (MRT, TXAA)
  - Concurrent multi-user beamforming (TX-SDMA)
  - Closed-Loop MIMO

- **Advantages** over Open-Loop Methods
  - Beamforming gain for range enhancement
  - Concurrent Transmissions (SDMA) on DL
  - Closed-Loop MIMO (Spatial Multiplexing) is more robust to low scattered channels than Open-Loop MIMO

Enabling Closed-Loop Transmission on DL

- Feedback
  - SS measures DL channel, sends channel information back to BS on feedback channel
  - **FDD** or **TDD**
  - Already in the standard

- Uplink Channel Reuse
  - BS determines DL channel response by measuring UL channel response from desired SS.
  - **TDD** only: (cannot use in FDD)
    - Assumes reciprocity in RF propagation and appropriately calibrated BS transmit and receive hardware
  - Can be used in current Standard but is not well supported!
  - 103r2 provides explicit support for Uplink Channel Reuse through the SS transmitting UL channel sounding waveforms

Advantages of UL Channel Reuse over Feedback in TDD

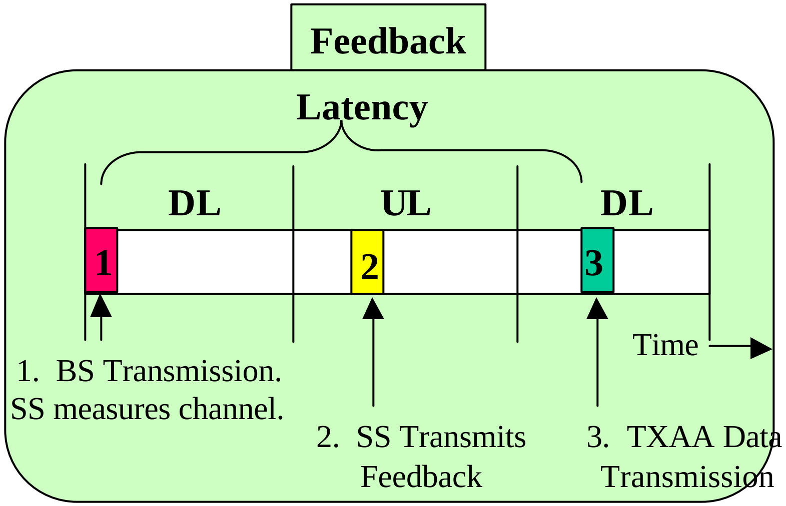
- Leverage UL SS data transmissions for free in some cases
- Feedback has poor scalability with the # of BS antennas
  - Feedback becomes difficult with large number of BS TX antennas
    - Amount of required feedback information becomes large
  - UL Channel Reuse schemes are independent of the # of BS antennas
- Channel estimation more difficult in feedback schemes:
  - Example: BS=8Tx, SS=1Rx
    - Feedback: SS must perform 8-source channel estimation on the DL
    - UL Channel Reuse: BS performs 1-source channel estimation on UL
- UL Channel Reuse has lower channel measurement latency
  - Reduces the velocities that can be supported

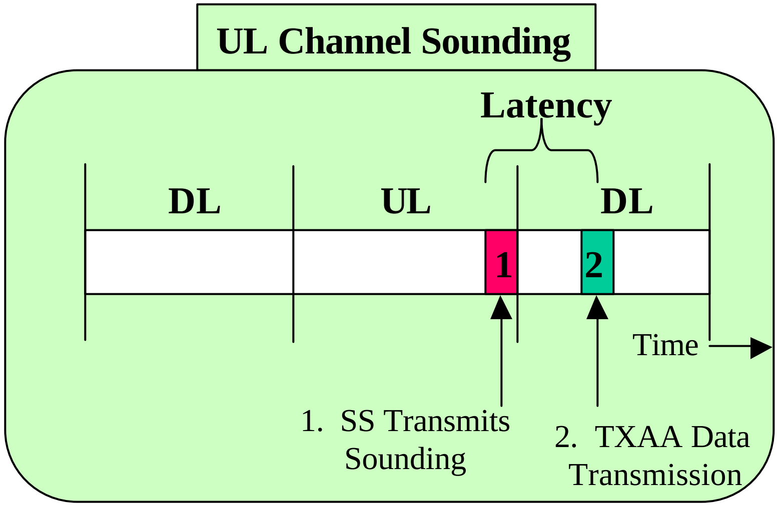
Channel Measurement Latency in TDD

- Feedback:
  - Min Latency = UL duration
  - Max Latency = 2DL + UL

- UL Channel Reuse
  - Nominal Latency = ½ DL
  - Min Latency = a few symbols
  - Max Latency < UL + DL

- Extra latency reduces the max velocity that can be supported





UL Channel Reuse in 802.16 TDD systems

- UL Channel Reuse can already be used in a TDD 802.16 system by leveraging UL data transmissions
- **Problem**: BS can leverage UL data transmissions only when their frequency occupancy encompasses the upcoming DL data transmission
  - Difficult to achieve in broadband data systems, especially when DL traffic levels >> UL traffic levels
- **Solution**: Use uplink sounding waveforms when needed
  - Transmitted by SS to enable the BS to calculate UL channel response
  - Not needed if UL data transmissions are sufficient for estimating desired channel response
  - Sounding strategy independent of the number of BS antennas
- **Purpose**: Introduce optional signaling methodology to support Closed-Loop Transmission based on Uplink Channel Reuse

Outline of Proposed Solution

- Optional Sounding Zone
- Explicit Sounding Instructions in the UL Map
- Piggybacking of sounding instructions onto DL data allocations in the DL-MAP
  - Coupled Sounding Instructions appended to DL Data allocations (new IE)
  - Uncoupled Sounding Instructions appended to DL Data allocations (new IE)
- Support for Closed-Loop MIMO

Sounding Zone Construction

- UL Map indicates location within the UL
  - Presence and characteristics can be made dynamic
- Consists of a small number of OFDMA symbols
- Frequency bandwidth divided into:
  - 192 frequency bins, each bin containing 9 subcarriers
- Frequency bandwidth divided into:
  - 48 Sounding Frequency Bands, each containing 192/48=4 frequency bins
    - 36 subcarriers in a Sounding Frequency Band
- Sounding Zone = 48 Sounding Frequency Bands by 1-8 OFDMA symbol intervals

Sounding Instructions (1/2)

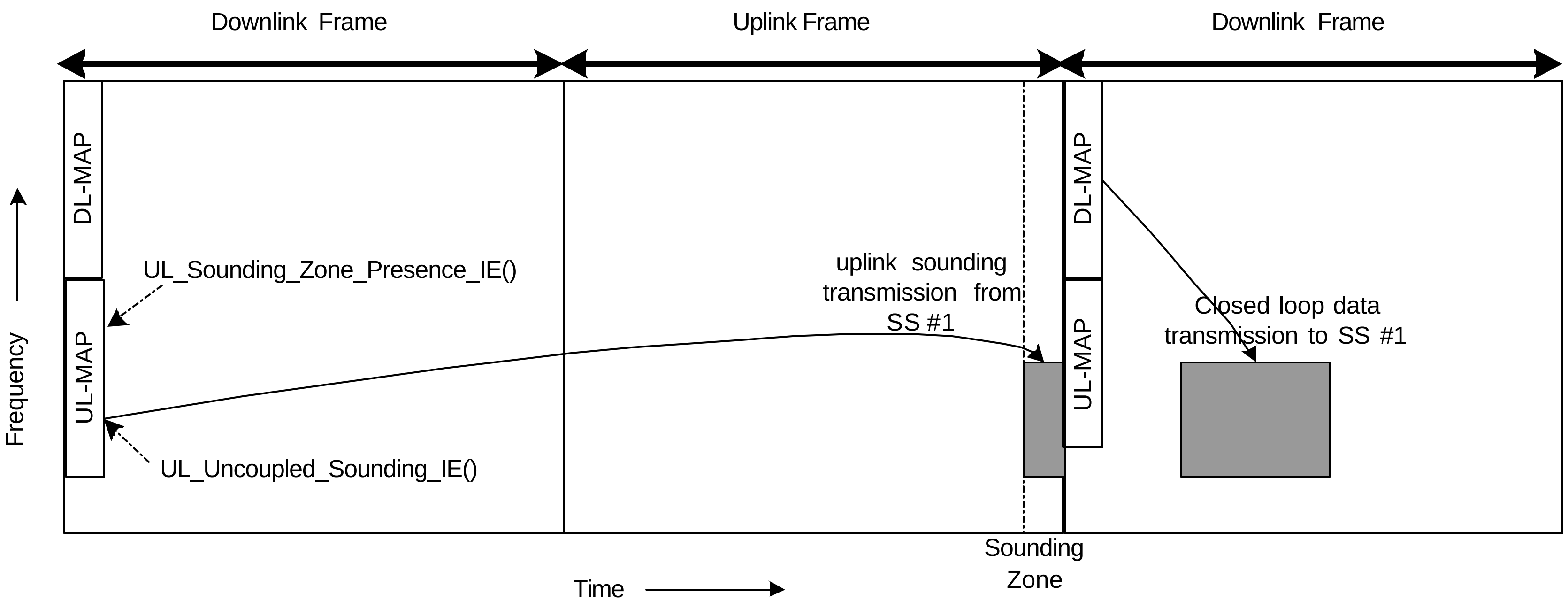
- Sounding Allocation:
  - Contiguous set of Sounding Frequency Bands
  - OFDMA Sounding Symbol
- Sounding Sequence Index
  - Multiple Sectors use different groups of sounding sequences (GCL sequences)
    - Sequence to use partially determined from CellID
  - Sequence waveform implicitly determined by the allocated subcarriers within the sounding allocation
  - All transmissions sharing the sounding allocation use the same underlying sequence with one of two means for enabling the BS to separate the transmissions….

Sounding Instructions (2/2)

- “Separability” Mode with Separability Parameter to handle multiple soundings on a single sounding allocation
  - Sequence Separability:
    - Frequency-domain phase shifts induce cyclic time shifts for multiple soundings on a sounding allocation
  - Decimation (i.e., frequency-interleaved allocation):
    - Decimation offset
- Multi-Antenna Mode
  - Sound one SS antenna or sound all SS antennas
- Implicit determination of separability parameters

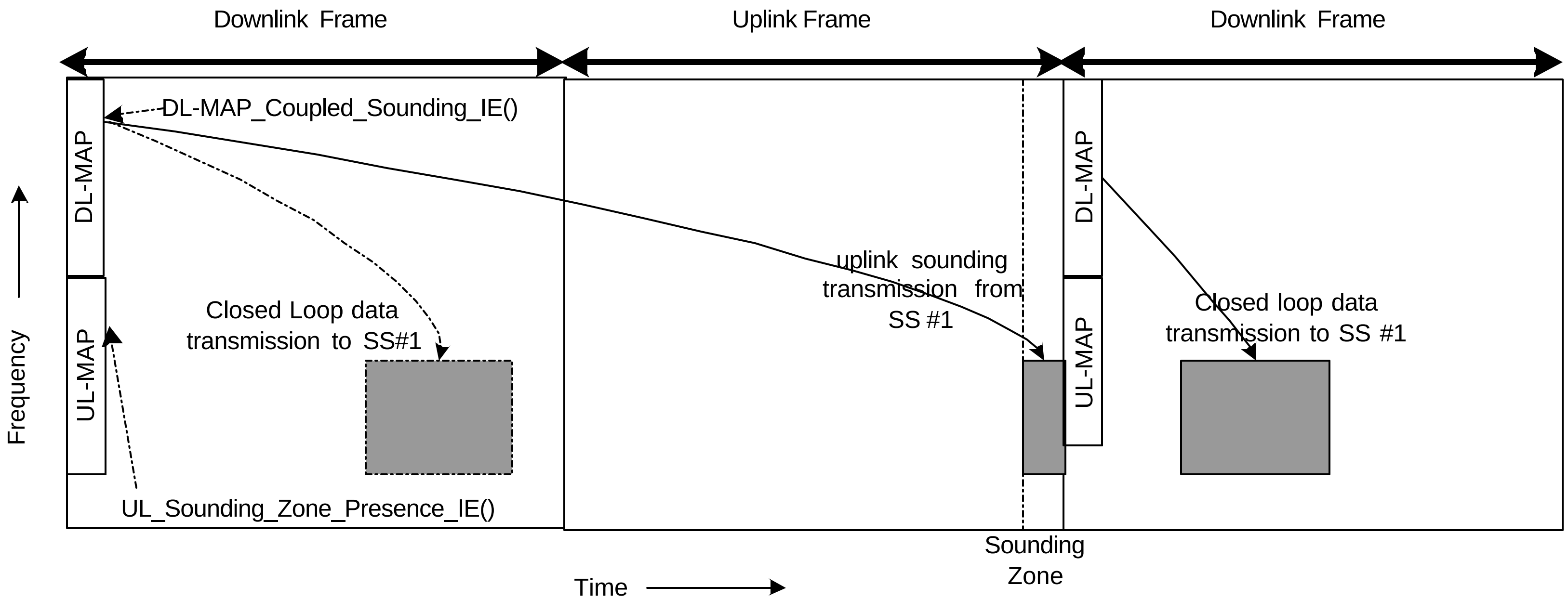
Explicit Sounding Instructions

- Presence of Optional Sounding Zone indicated in UL-MAP
- New IE for providing sounding instructions in the UL-MAP



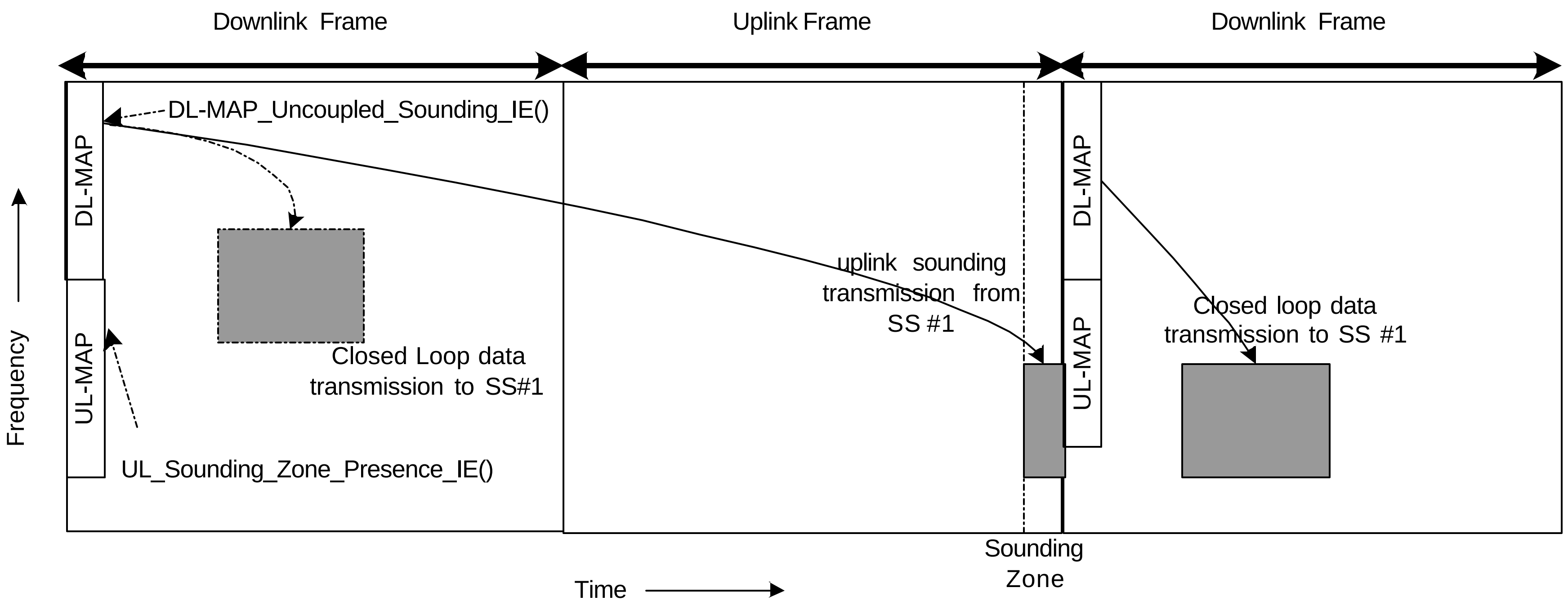
Combining Data Allocations and Sounding Instructions – Coupled Method

- Simultaneously allocate a DL data transmission and UL sounding in the DL-MAP
- Coupled Sounding: Frequency occupancy of Sounding implicitly determined by DL data transmission



Combining Data Allocations and Sounding Instructions – Uncoupled Method

- Simultaneously allocate a DL data transmission and UL sounding in the DL-MAP
- Complete set of sounding instructions independent of the DL data transmission



Closed-Loop MIMO Support

- Create new extended IEs for the DL-MAP
  - Combine MIMO allocations and sounding instructions with additional fields needed for CL-MIMO
  - Signaling strategy identical to non-MIMO case

Backward Compatibility Proposal

- 2048 FFT sizes:
  - Technique is optional
  - BS must not schedule legacy SSs in UL frames that have a sounding zone
- All other FFT sizes:
  - Technique is optional
  - SSs must know how to handle the presence of an UL Sounding Zone

Comments Received & Our Response

- Concerns about ability to accurately estimate the channel
  - 103r2 shows performance results in mobile spatial channels
- Cannot provide indication of Interference received by SS
  - Not needed by generic closed-loop transmission techniques
  - 103r2 would not replace existing methods of telling the BS the average SINR seen at the SS
- Collisions in sounding waveforms without cell planning
  - 103r2 add support for optional scrambling of the sounding waveforms based on PRBS generator

Summary

- Lower Latency solution compared to Feedback
- Fast turnaround to support mobile channels
- Dynamic and flexible sounding instructions
- Low overhead transmissions
- Support for multiple concurrent sounding transmissions on a sounding allocation
- Solution independent of number of BS antennas
- Flexibility in handling SSs with varying # of antennas
- Sequence "reuse" strategy for multi-cell co-channel deployments
- Support for Closed-Loop MIMO

Proposed Text Changes

- See Document C80216e-04/103r2