# 802.16m Downlink Unicast Service Control Channel (USCCH) Multiplexing

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Re: Call for Contributions on Project 802.16m System Description Document (SDD)
Downlink control channel structure

Venue: Macau, China

Base Contribution:

Purpose: Discussion and consideration for 802.16m SDD

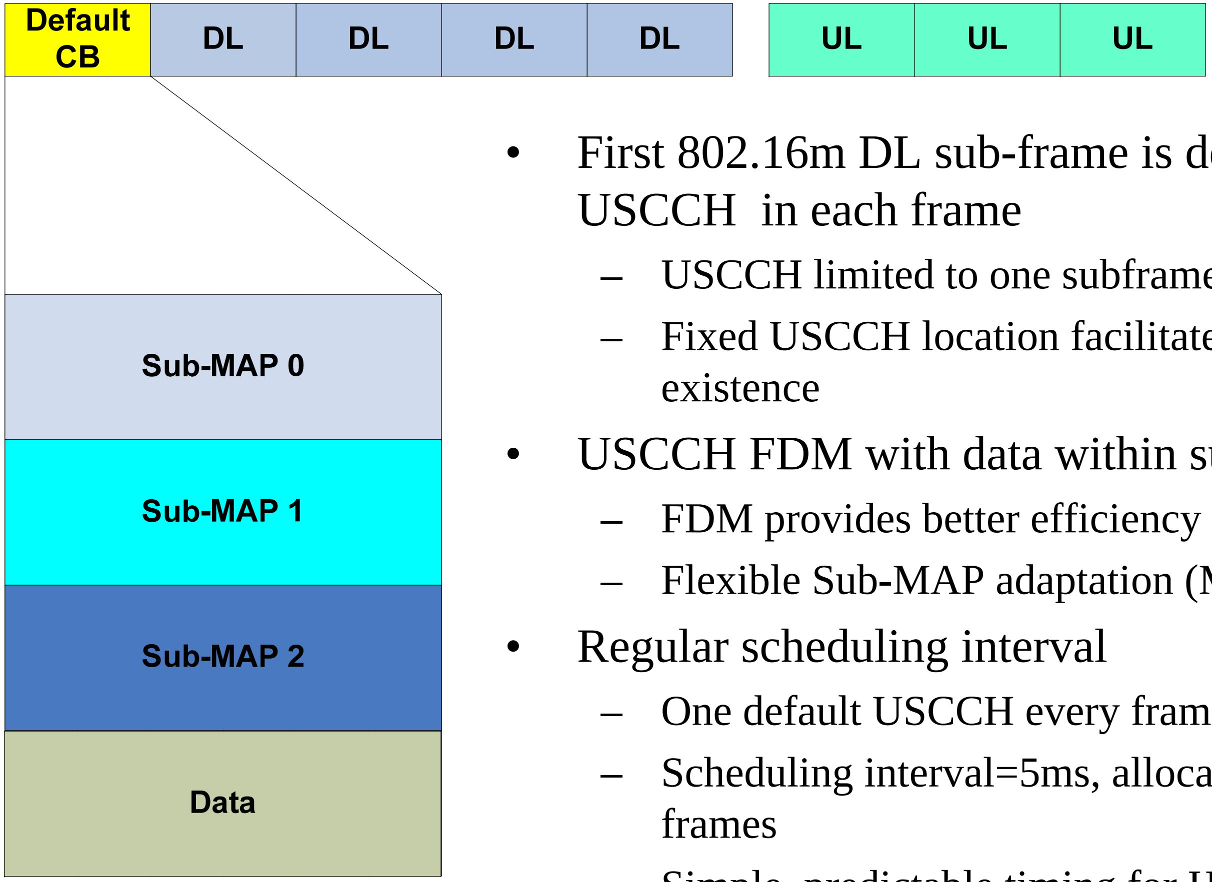
# Outline

- Downlink Unicast Service Control Channel (USCCH) Multiplexing
  - Control blocks FDM with data within subframe
  - Control blocks transmitted once every n subframes
- Latency analysis
- Analysis of power saving efficiency
- Co-existence analysis
- Summary and Recommendations

# Default and Optional USCCH

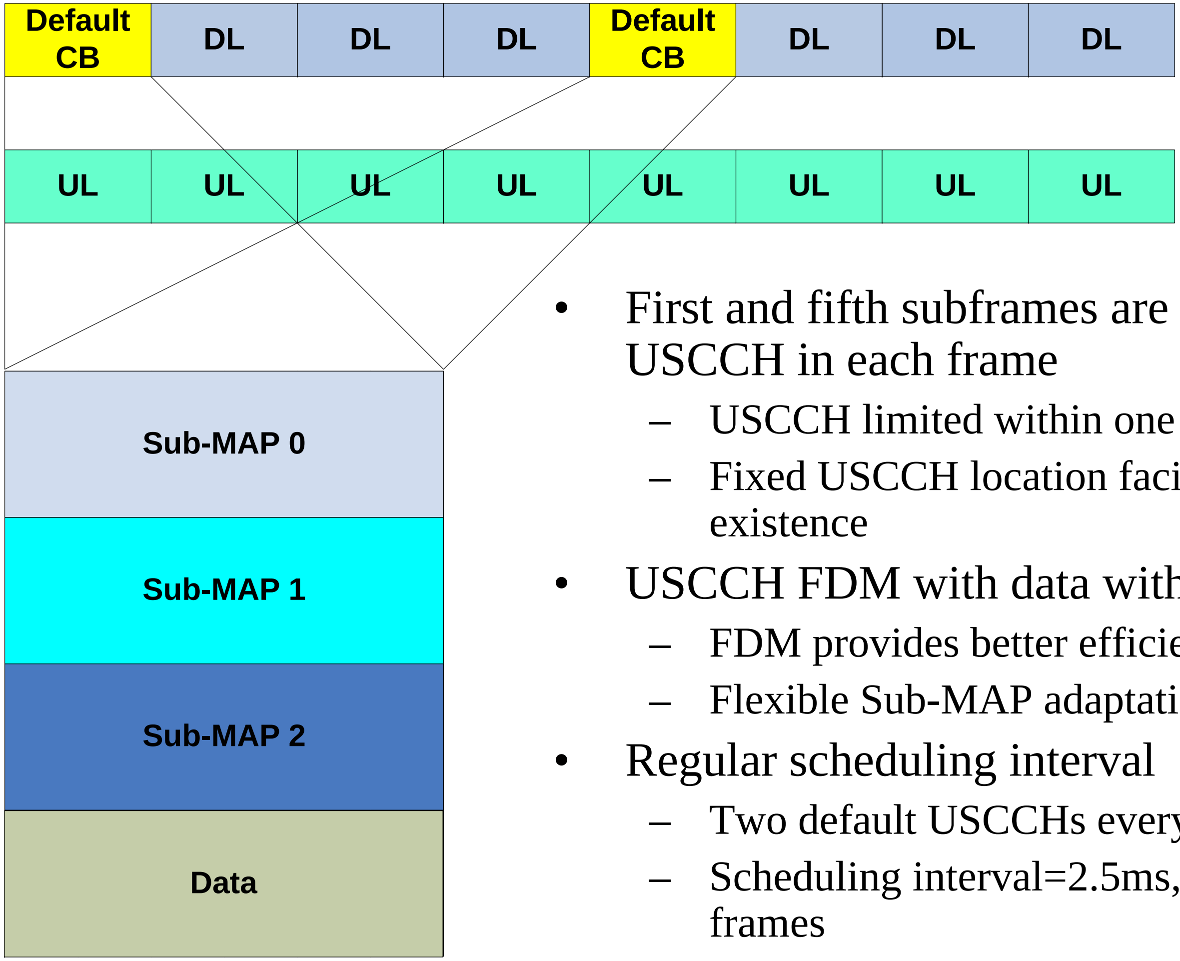
- Default USCCH monitored by all active users
  - Default USCCH may contain control information other than unicast resource allocation
  - Default USCCH located at fixed locations to support micro sleep and multi-radio co-existence
- Optional USCCH only monitored by users configured/negotiated to receive the optional USCCH
  - Optional USCCH only contains control information for unicast resource allocation
  - Optional USCCH also located in regular intervals to maintain HARQ timing
  - Optional USCCH location may be semi-statically configured

# Default USCCH Control Block (CB) Location (TDD)



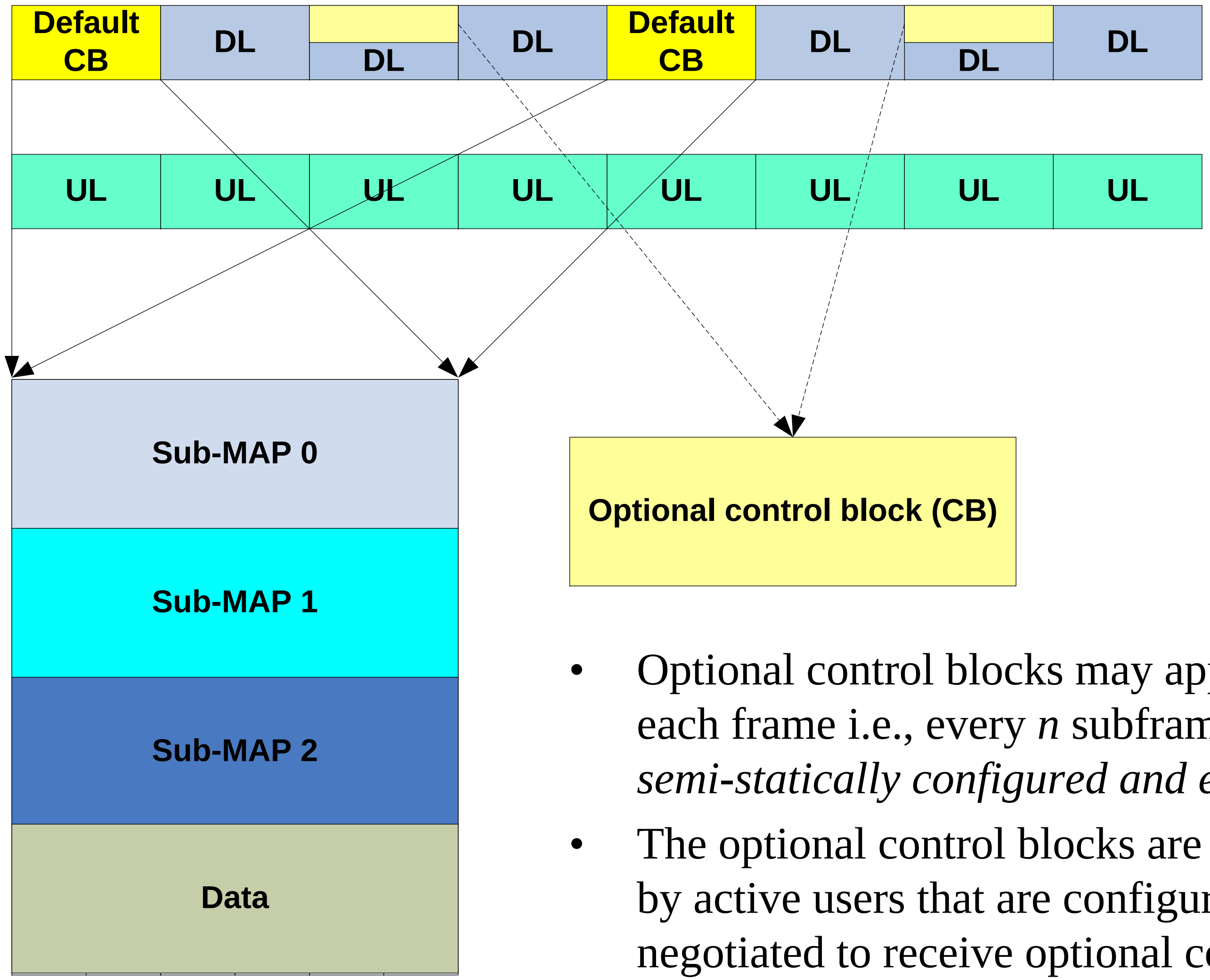

- First 802.16m DL sub-frame is default location of USCCH in each frame
  - USCCH limited to one subframe => overhead <20~25%
  - Fixed USCCH location facilitates power saving, co-existence
- USCCH FDM with data within sub-frame
  - FDM provides better efficiency and robustness
  - Flexible Sub-MAP adaptation (MCS, power, FFR)
- Regular scheduling interval
  - One default USCCH every frame
  - Scheduling interval=5ms, allocations for multiple sub-frames
  - Simple, predictable timing for HARQ
- Default USCCH contains unicast service control information for all active users

# Default USCCH CB Location (FDD)



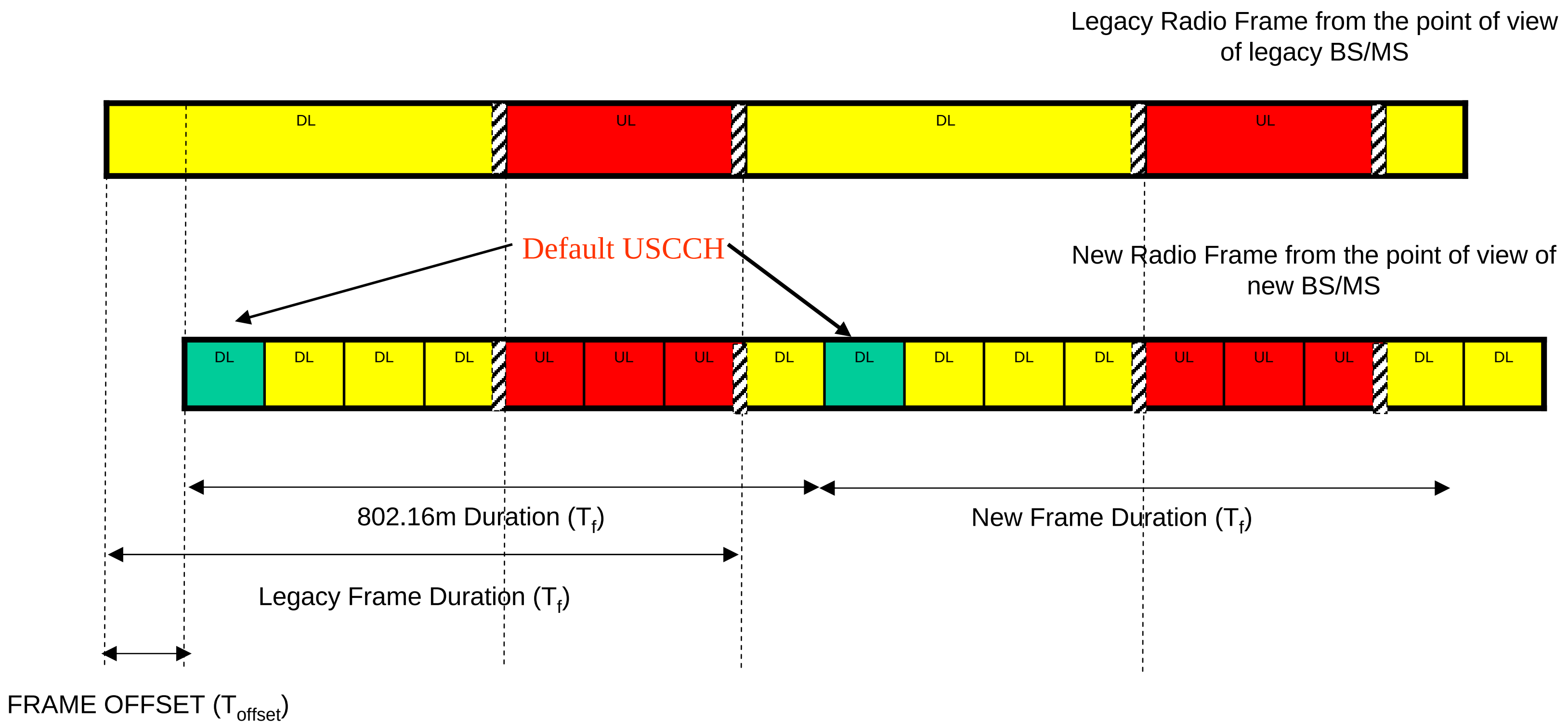

- First and fifth subframes are default locations for USCCH in each frame
  - USCCH limited within one subframe => overhead <25%
  - Fixed USCCH location facilitates power saving, co-existence
- USCCH FDM with data within sub-frame
  - FDM provides better efficiency and robustness
  - Flexible Sub-MAP adaptation (MCS, power, FFR)
- Regular scheduling interval
  - Two default USCCHs every frame
  - Scheduling interval=2.5ms, allocations for multiple sub-frames
  - Simpler timing relation for HARQ
- Default USCCH contains unicast service control information for all active users

# Optional USCCH CB for Low Latency Users



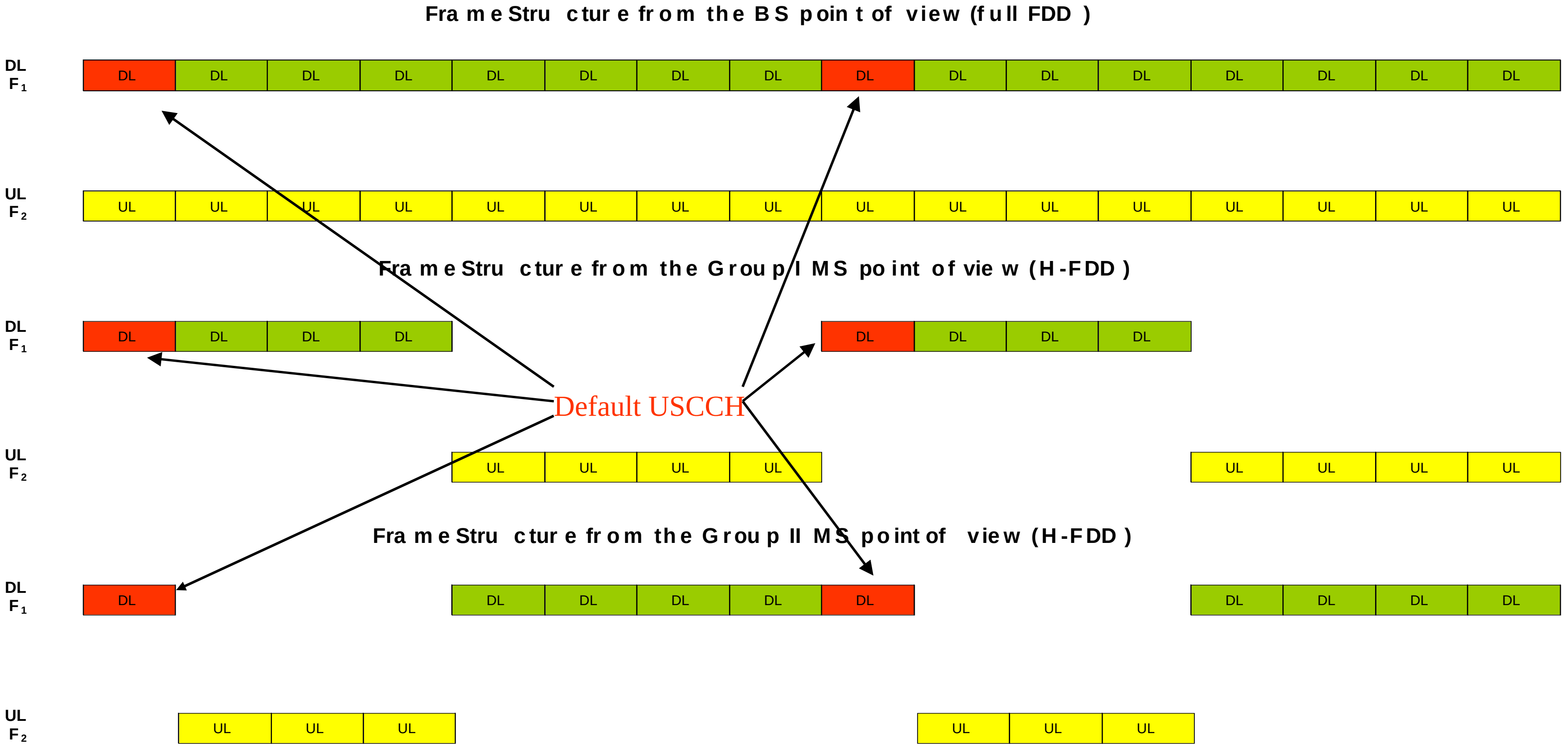

- Optional control blocks may appear more often in each frame i.e., every *n* subframes, where *n is semi-statically configured and equal to 2, 4, …*
- The optional control blocks are only monitored by active users that are configured /pre-negotiated to receive optional control blocks for faster scheduling and reduced latency

# Configuration with Legacy Support




- When operating with legacy support, the default USCCH is located in the first subframe of the 802.16m frame

# Configuration for HFDD




- USCCH located in the first and fifth 802.16m subframe
- HFDD complementary grouping and scheduling supported

# Access Latency Calculation

- Frame duration ($T_F$)
- Number of sub-frames per frame (N)
- Number of scheduling event per-frame (n)
- Number of sub-frames between two consecutive scheduling events (m)
- Time offset of $i_{th}$ scheduling event from the last scheduling event of previous frame ($T_s(i)$)
- Queuing/frame alignment latency ($T_q$)
  - Latency from packet arrival to being scheduled

$$T_q = \frac{1}{n}\sum_{i=1}^{n}\left\{T_s(i) - \frac{i-0.5}{n}T_F\right\}$$

- Data transmission latency ($T_t$)
  - Latency from packet being scheduled to being transmitted

$$T_t = \frac{1}{m}\sum_{i=1}^{m} iTTI = \frac{(m+1)}{2}TTI$$

- Retransmission turn around time for transmission in nth subframe ($T_r(n)$)
  - Latency from the end of previous transmission to the end of current re-transmission
  - Typically in multiple of frames subject to HARQ NACK delay and processing delay
- Initial HARQ retransmission probability ($p_h$)
- Average HARQ retransmission latency ($T_h$)

$$T_h = \frac{p_n}{N}\sum_{n=1}^{N} T_r(n)$$

- BS Processing latency ($T_d$) [802.16m-08/003r1]
  - Latency from the end of packet transmission to the packet being decoded and sent to IP SAP at the receiver

# Average Access Latency (example)

| Stage | Description | Latency Value (TDD 5:3) | | | Latency Value (FDD) | | |
|---|---|---|---|---|---|---|---|
| | | n=4 | n=2 | n=1 | n=4 | n=2 | n=1 |
| 1 | Queuing Delay ($T_d$) | 2.5ms | 1.883ms | 1.27ms | 1.25ms | 0.649ms | 0.341ms |
| 2 | Data transmission time ($T_t$) | 1.851ms | 1.111ms | 0.617ms | 1.543ms | 0.926ms | 0.617ms |
| 3 | Retransmission latency ($T_r$) (30% initial retrans. prob.) | 2.1 ms | 1.5ms | 1.5ms | 1.5ms | 1.5ms | 1.5ms |
| 4 | Processing latency ($T_d$) | 1.23 ms | 1.23ms | 1.23ms | 1.23 ms | 1.23ms | 1.23ms |
| 5 | Total* | 7.7 ms | 5.7ms | 4.6ms | 5.5ms | 4.3ms | 3.7ms |

Control block in every subframe does not provide significant latency reduction over control block every 2 subframes

* Average latency may vary with different DL/UL ratio in TDD mode

* R6 transfer delay and ASN-GW processing delay are not included

# MS Power Saving (Micro Sleep) Requirements

| Power State | Power saved | Resume time |
|---|---|---|
| RX/TX chains off | ~600mW | Few usec |
| RF synthesizer off | Additional ~100mW | ~500usec |
| Switch to Slow Clock | Additional 50-150mW | ~10ms |

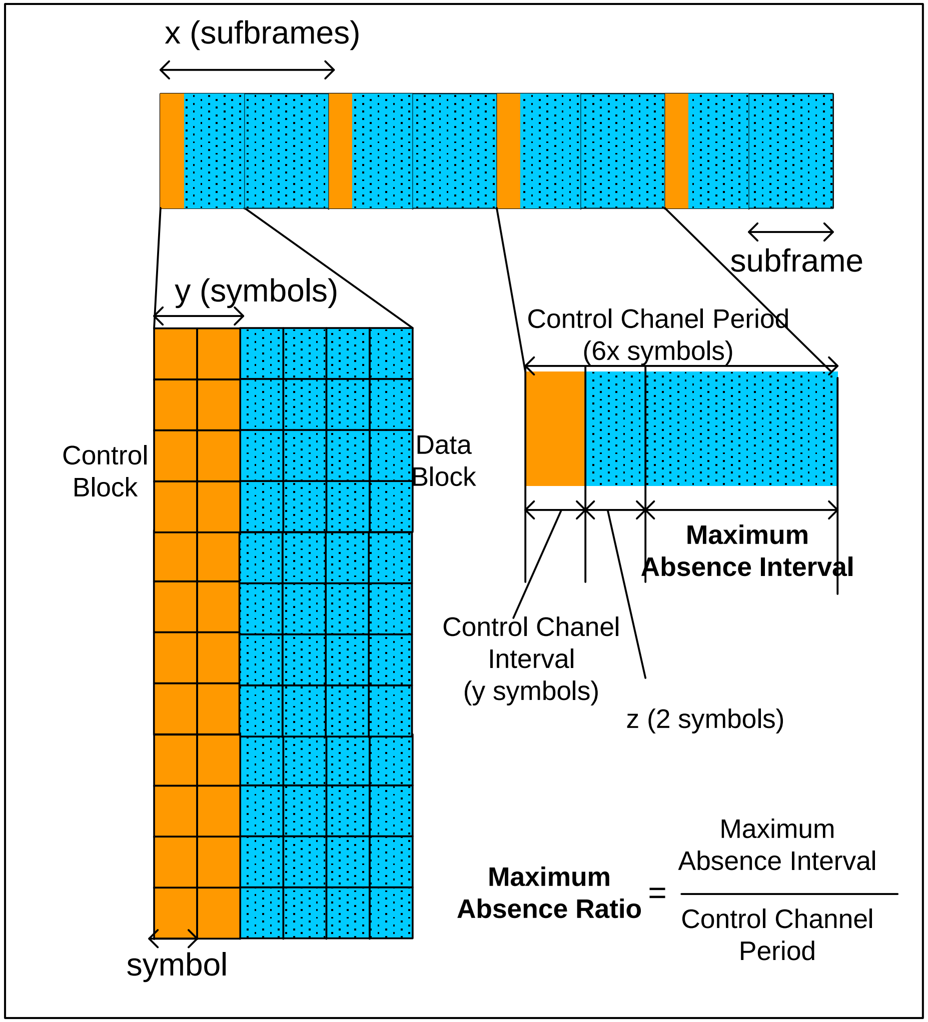
- Low control channel duty cycle
  - Low control channel duty cycle reduces Rx chain ‘on time’ for MS with no traffic
- Low control channel processing latency
  - Low complexity control channel design
  - Low processing latency allows an MS with no traffic to quickly turn off Rx chain
- Long inter-control channel idle time
  - A longer period between control channel transmissions improves power saving efficiency

# TDM-based Co-Located Coexistence Requirements

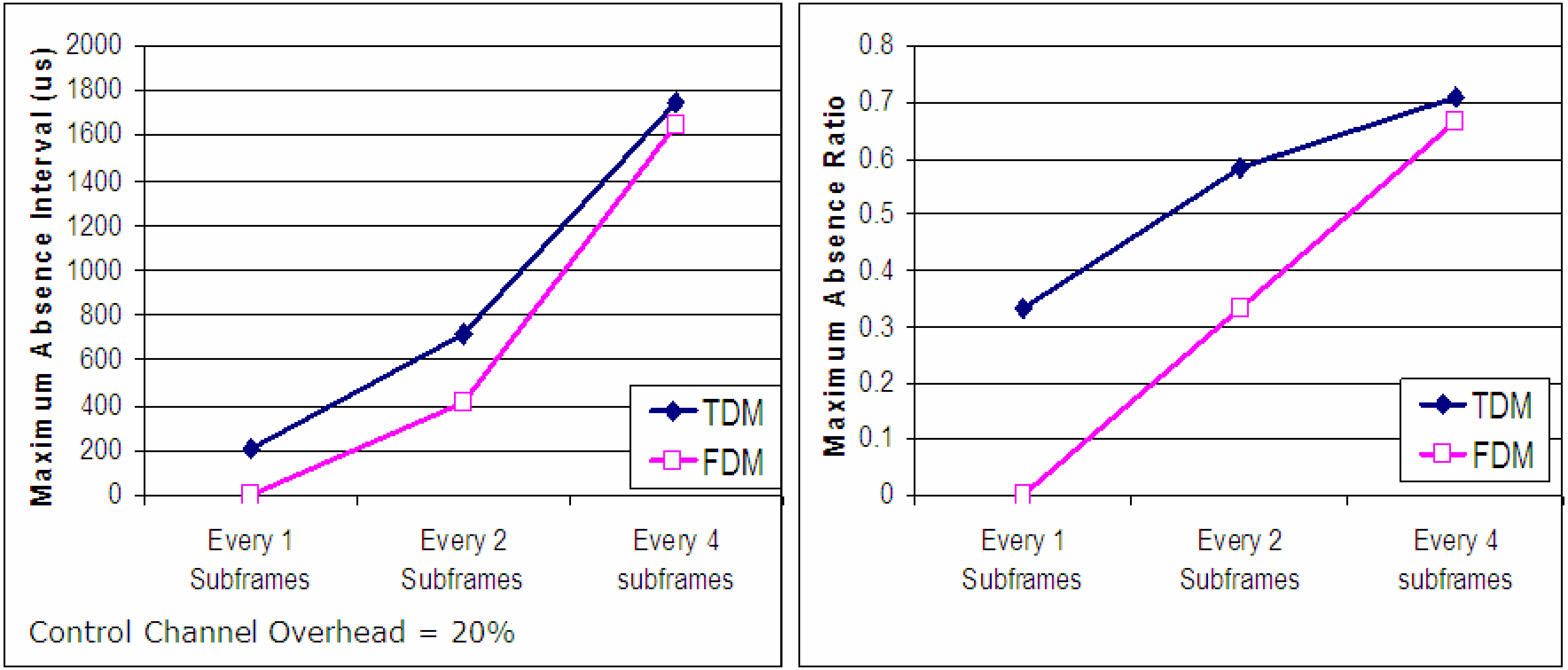
- TDM: media independent & universal solution for co-located multi-radio coexistence
  - Time multiplex transmission and reception of different radios, i.e. transmission on one radio must be prohibited for the others to receive
    - RF techniques (filtering) may not be sufficient to suppress interference between co-located 802.16m and non 802.16m radios in adjacent bands
  - Design principles to support TDM-based co-located coexistence operation
    - Predictability: the activities of a radio follow predictable pattern
    - Compressibility: the capability of reducing the duty cycle of a radio
    - Schedulability: the capability of how flexible and responsive a radio can schedule its activity according to the activities of other co-located radios
- Control Channel Design for Predictability & Compressibility
  - Short control channel duration and low control channel duty cycle increases the portion of time available for sharing with other co-located radios
  - Long inter control channel idle time provides sufficient preparation time and operation time for other co-located radio activities

# Metrics for Micro Sleep and Co-Located Co-existence

- **Mobile Station Usage**
  - decode control channel to receive the data allocation information
  - turn off the radio to save power or operate other co-located radios, such as 802.11 or Bluetooth, if no information of interest on data channel
- **Configurations**
  - x: control channel period to indicate how often control channel appears
  - y: number of symbols occupied by control channel
  - z: the processing time to decode control information
- **Metrics**
  - Maximum Absence Interval: the maximum time interval that an 802.16m MS can turn off its radio
  - Maximum Absence Ratio: the maximum fraction of time that an 802.16m MS can turn off its radio



# Impact on Maximum Absence Interval & Ratio




- "USCCH every 4 subframes" achieves 70% maximum absence ratio and over 1.6ms maximum absence interval, regardless of FDM or TDM within sub-frame
  - Bluetooth friendly co-location support (one Bluetooth slot is 625us)
- "USCCH every 1 subframe" constrains micro sleep and co-located coexistence operation

# Summary and Recommendation

- FDM within each sub-frame provides
  - Better coverage
  - Flexibility to trade data power resource for control channel capacity
  - Maintain resource block size
- Control blocks transmitted once every n (n>1) subframes provides
  - Better power saving efficiency
  - Better co-existence flexibility
  - Slightly increased latency
- Proposed SDD text modification for USCCH location in C80216m-08/297
  - USCCH control blocks are classified as default or optional control blocks. Default control blocks are monitored by all users, while optional control blocks are only monitored by active users that are configured /pre-negotiated to receive optional control blocks for faster scheduling and reduced latency.
  - In the TDD mode, the default control block for unicast services is located at the first 802.16m DL sub-frame of each frame; in the FDD mode, the default control blocks for unicast services are located at the first and fifth 802.16m DL sub-frame of each frame.
  - Optional control blocks may appear more often in each frame i.e., every *n* subframes, where *n is semi-statically configured and is equal to 2, 4, …*
  - Adopt figure xxx, yyy, zzz (slides 6, 7, 8) for SDD