802.16m Downlink Unicast Service Control Channel (USCCH) Multiplexing

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Source:
Hujun Yin (hujun.yin@intel.com) Intel Corporation
Yuval Lomnitz (yuval.lomnitz@intel.com) Intel Corporation
Jing Zhu (jing.z.zhu@intel.com) Intel Corporation
Sassan Ahmadi (sassan.ahmadi@intel.com) Intel Corporation
Roshni Srinivasan (roshni.m.srinivasan@intel.com) Intel Corporation

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

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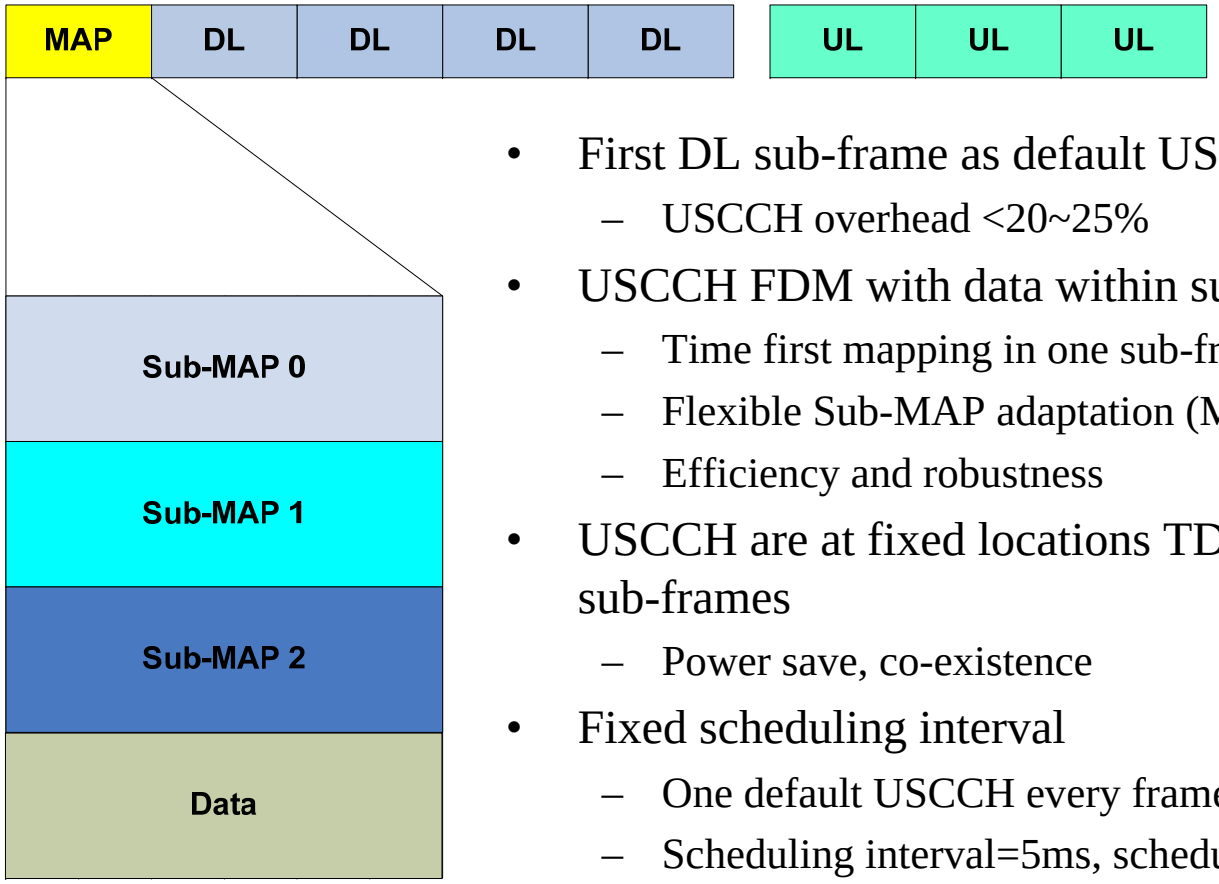
Outline

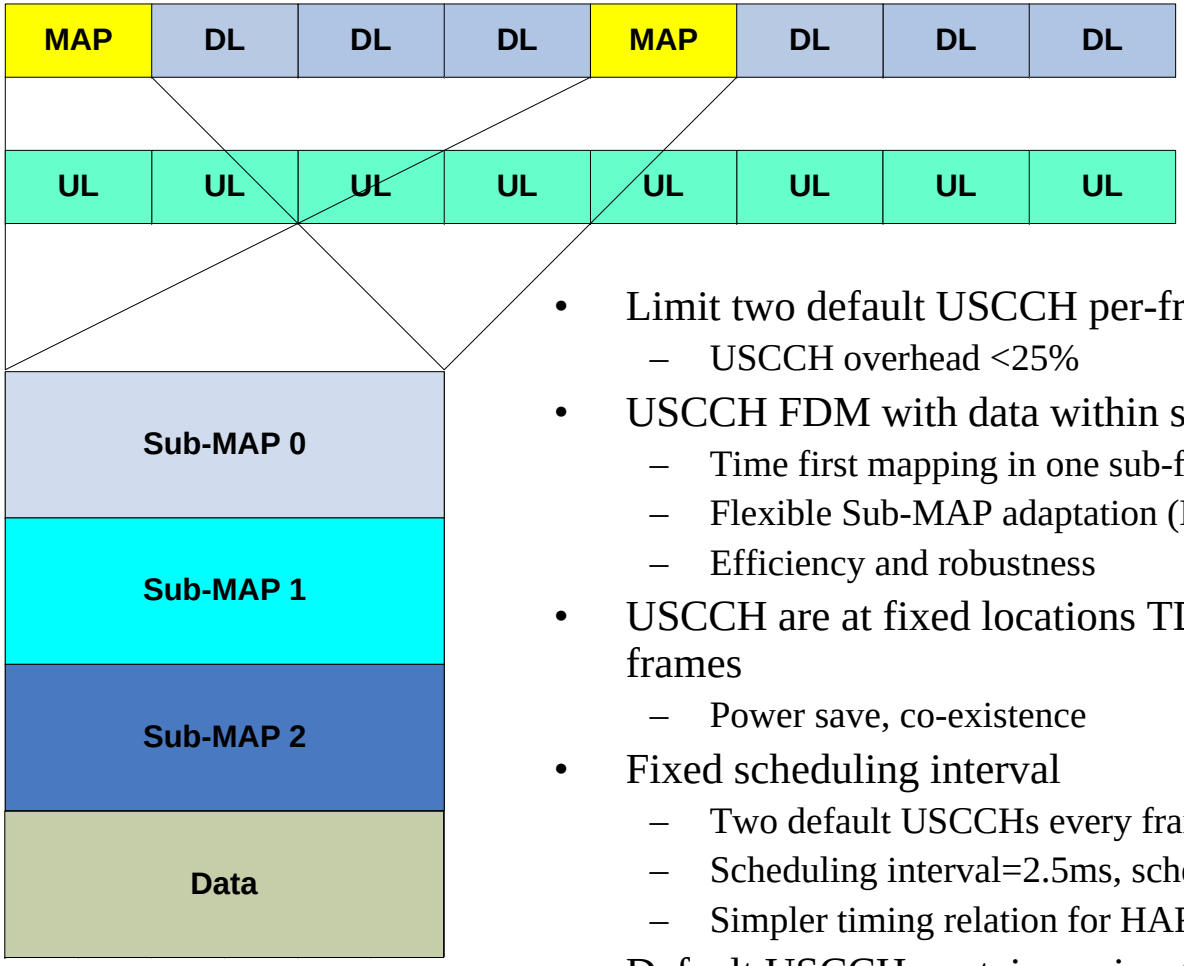
- Downlink Unicast Service Control Channel Multiplexing
  - FDM with subframe, TDM between subframes
- Latency analysis
- Power efficiency analysis
- Co-existence analysis
- Summary and Recommendations

Default USCCH Location (TDD)



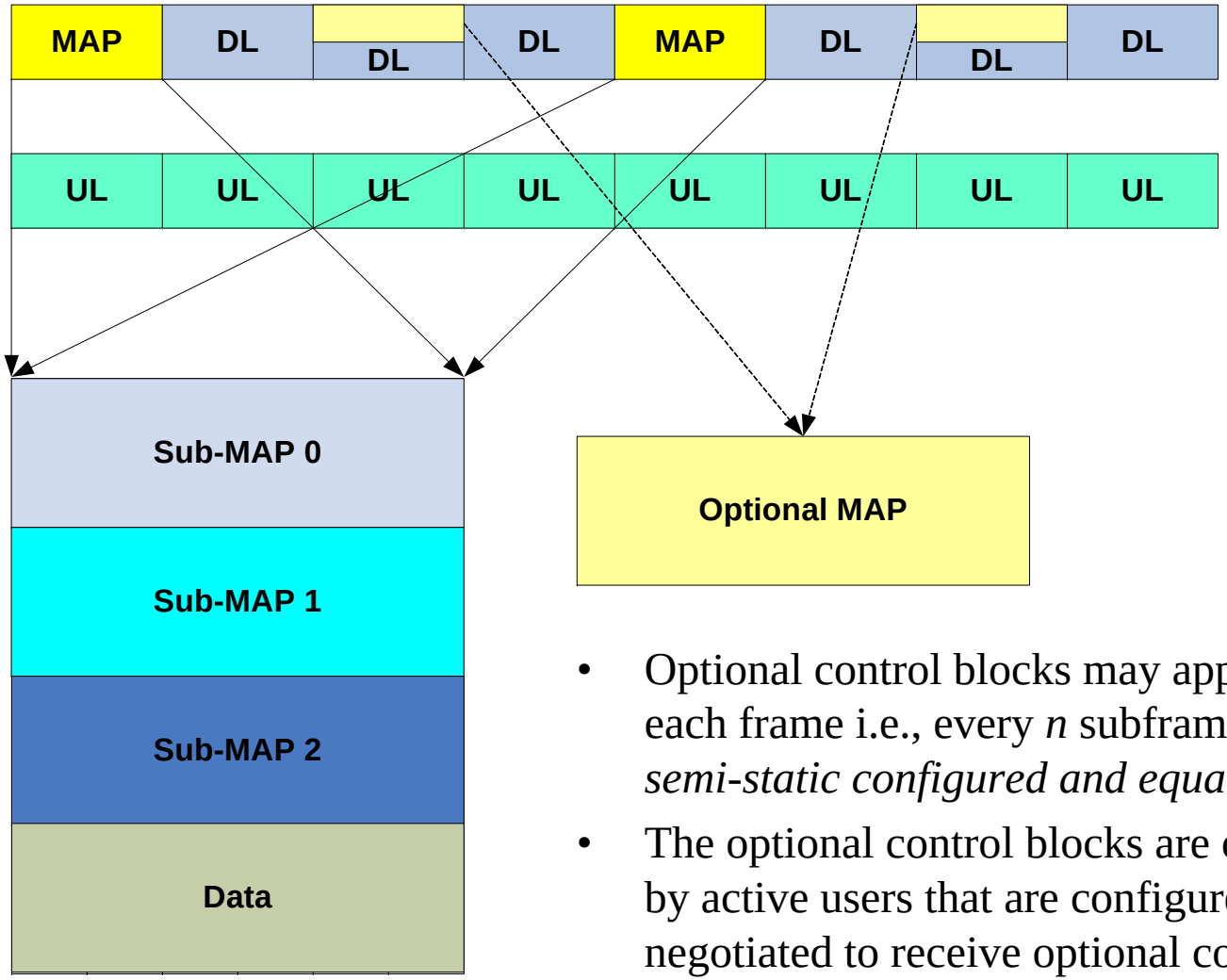
- First DL sub-frame as default USCCH in each frame
  - USCCH overhead <20~25%
- USCCH FDM with data within sub-frame
  - Time first mapping in one sub-frame
  - Flexible Sub-MAP adaptation (MCS, power, FFR)
  - Efficiency and robustness
- USCCH are at fixed locations TDM with data in unit of sub-frames
  - Power save, co-existence
- Fixed scheduling interval
  - One default USCCH every frame
  - Scheduling interval=5ms, schedule for multiple sub-frames
  - Simpler timing relation for HARQ
- Default USCCH contains unicast service control information for all active users

Default USCCH Location (FDD)



- Limit two default USCCH per-frame
  - USCCH overhead <25%
- USCCH FDM with data within sub-frame
  - Time first mapping in one sub-frame
  - Flexible Sub-MAP adaptation (MCS, power, FFR)
  - Efficiency and robustness
- USCCH are at fixed locations TDM with data in unit of sub-frames
  - Power save, co-existence
- Fixed scheduling interval
  - Two default USCCHs every frame
  - Scheduling interval=2.5ms, schedule for multiple sub-frames
  - Simpler timing relation for HARQ
- Default USCCH contains unicast service control information for all active users

Optional USCCH (MAP) for Low Latency Users

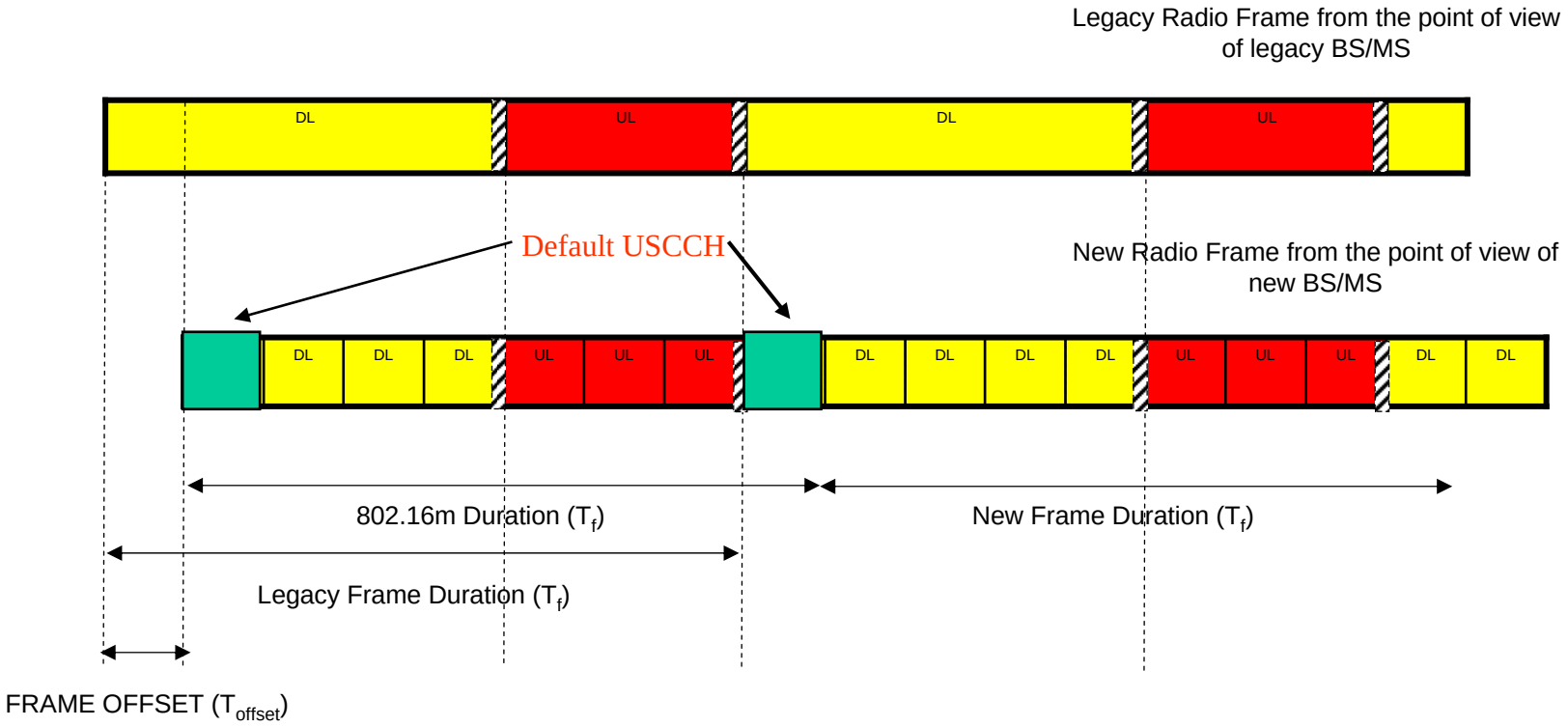


- Optional control blocks may appear more often in each frame i.e., every *n* subframes, where *n is semi-static configured and equal to 2, 4, …*
- The optional control blocks are only monitored by active users that are configured /pre-negotiated to receive optional control blocks for faster scheduling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

Why Default and Optional USCCH?

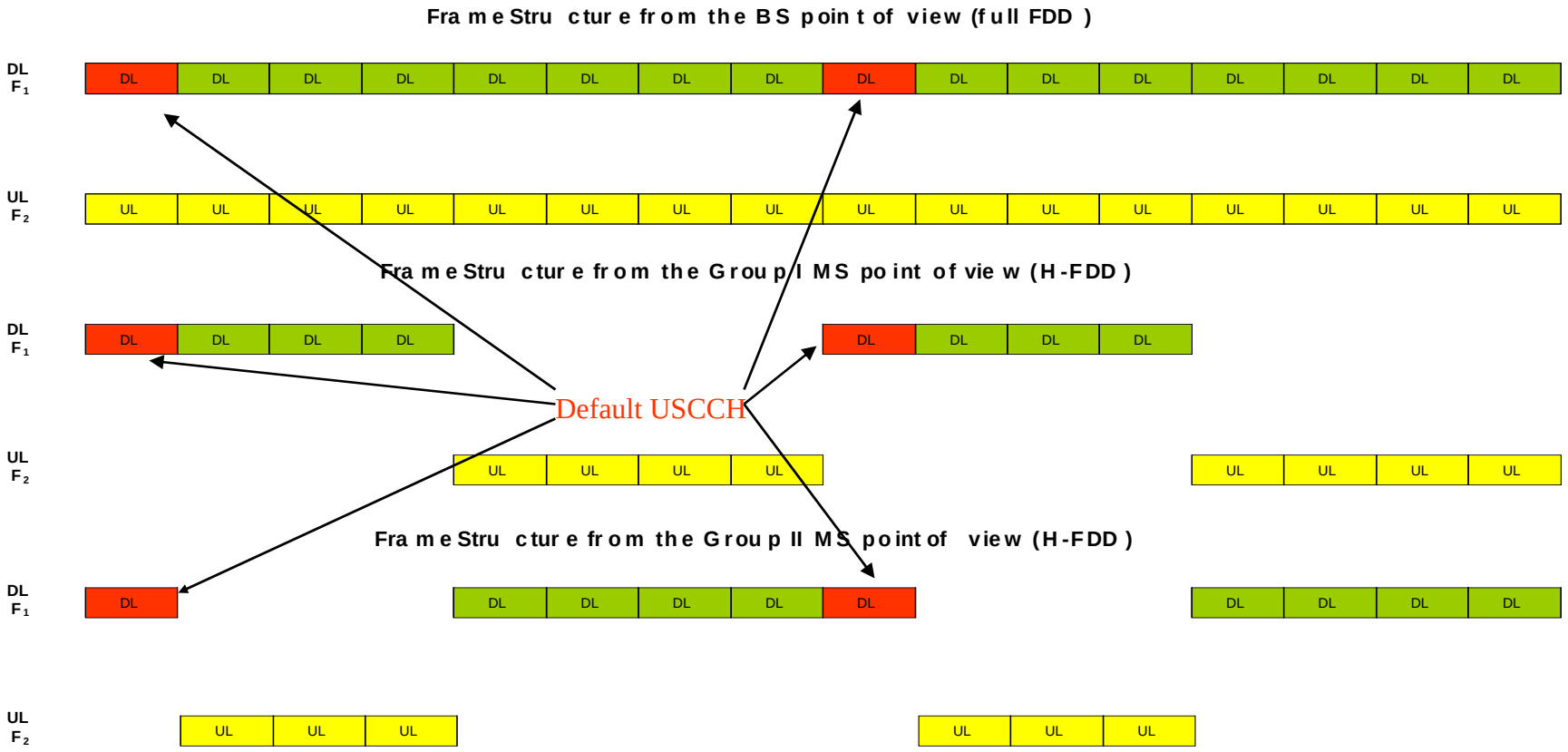
- Default USCCH are monitored by all active users
  - Default USCCH may contain control information other than unicast resource allocation
  - Default USCCH located at fixed locations to support micro sleep and multi-radio co-existence
- Optional USCCH only monitored by users configured/negotiated to 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 relation
  - Optional USCCH location may be semi-static configured

Configuration with Legacy Support



- When operating with legacy support, the default USCCH locates in the first subframe of the 16m frame

Configuration for HFDD



- USCCH located in the first and fourth subframe
- Support HFDD complementary grouping and scheduling

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 4:4)			Latency Value (FDD)		
		n=4	n=2	n=1	n=4	n=2	n=1
1	Queuing Delay (T_d)	2.5ms	1.883ms	1.575ms	1.25ms	0.649ms	0.341ms
2	Data transmission time (T_t)	1.543ms	0.926ms	0.617ms	1.543ms	0.926ms	0.617ms
3	Retransmission latency (T_r) (30% initial retrans. prob.)	2.25 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*	7.5 ms	5.5ms	4.9ms	5.5ms	4.3ms	3.7ms

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

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

Impact on MS Power Save (Micro Sleep)

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

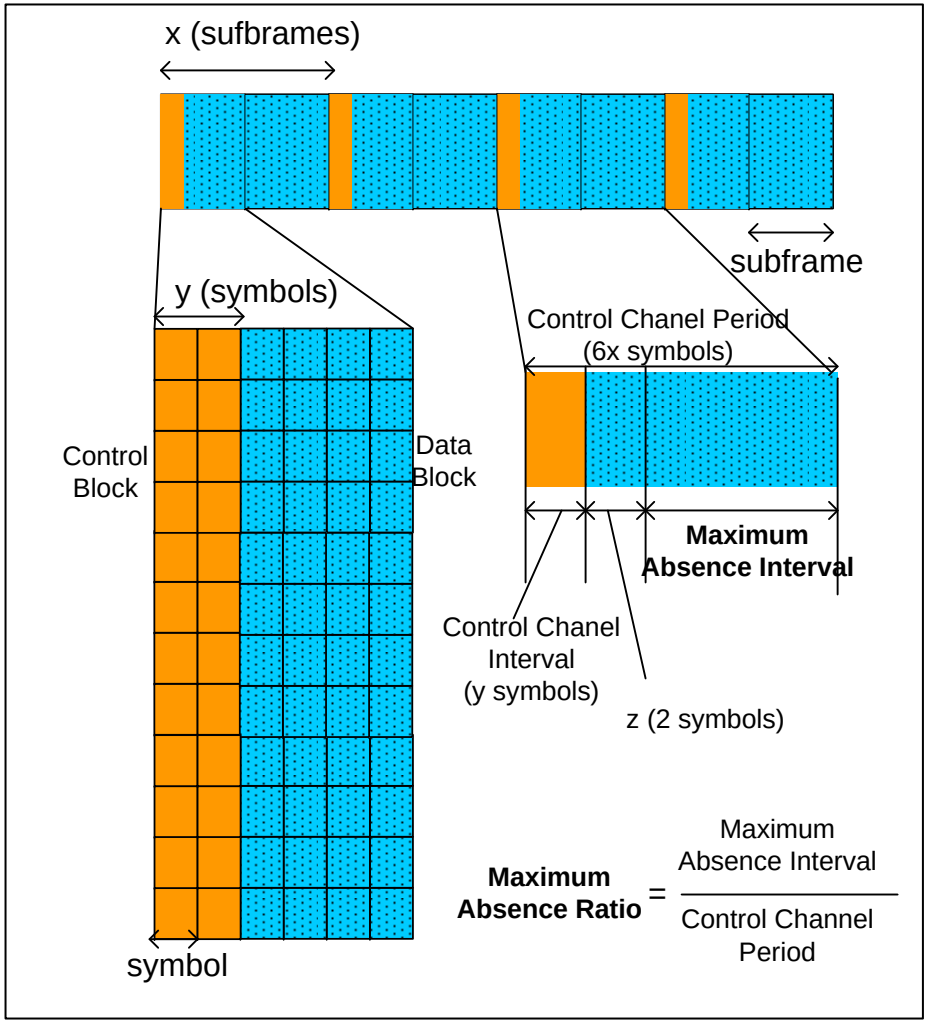
- Short control channel duration
  - Low control channel duty cycle reduces Rx chain on time for MS with no traffic
- Low control channel processing latency
  - Low processing latency allow MS with no traffic quickly turn off Rx chain
  - Low complexity control channel
- Long inter-control channel idle time
  - More efficiently save power with longer off period

Impact on TDM-based Co-Located Coexistence

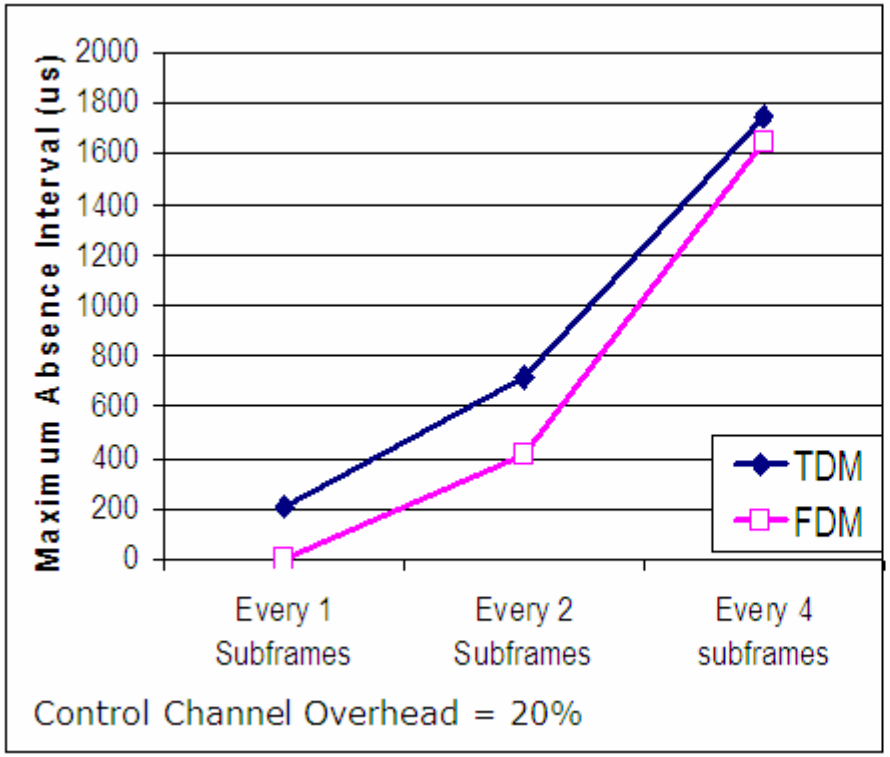
- TDM: media independent & universal solution to co-located multi-radio coexistence
  - Time multiplex transmission and reception of different radios, i.e. transmission on one radio must be prohibited for the others to receive
    - RF techniques (filtering) may not be sufficient to suppress interference 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 increase the portion of time available to share with other co-located radio
  - Long inter control channel idle time provides sufficient preparation time and operation time for other co-located radio activities

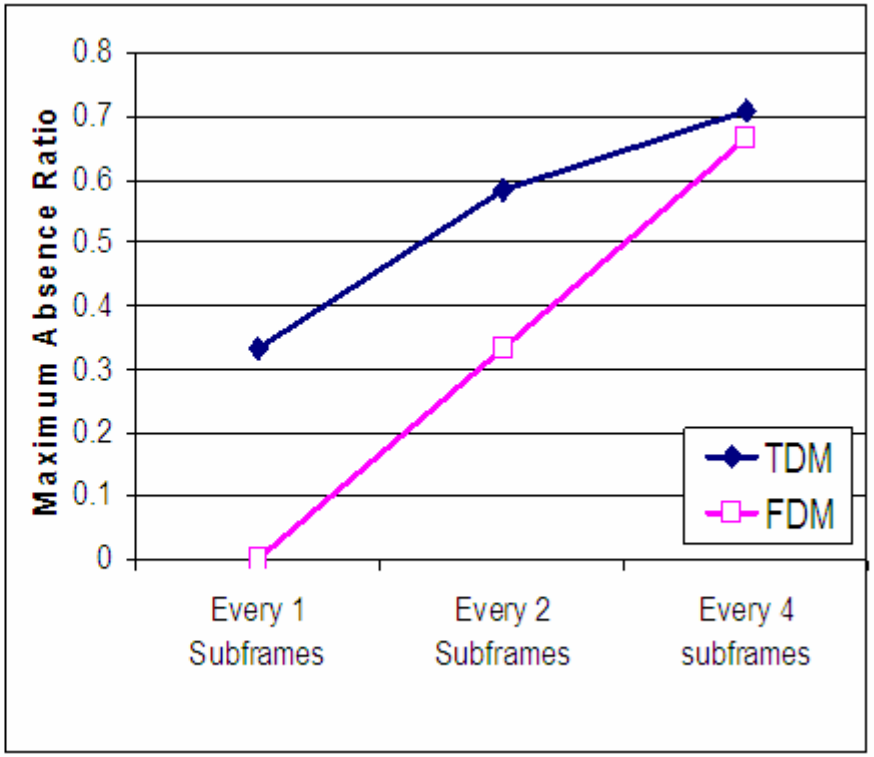
Metrics for Micro Sleep and Co-Located Co-existence

- **Mobile Station Usage Description**
  - 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 a 802.16m MS can turn off its radio
  - Maximum Absence Ratio: the maximum time ratio that a 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
  - Friendly to support Bluetooth co-location (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
- TDM between sub-frames (one control block in multiple sub-frames) provides
  - Better power saving efficiency
  - Better co-existence flexibility
  - Slightly increased latency
- Propose USCCH location configuration change in C80216m-08/297
  - In TDD duplex scheme, the default control block for unicast services is located at the first sub-frame of each frame; and in FDD duplex scheme, the default control blocks for unicast services are located at the first and fourth sub-frame of each frame
  - Optional control blocks may appear more often in each frame i.e., every *n* subframes, where *n is semi-static configured and equal to 2, 4, …*
  - The default control blocks are monitored by all users, while 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.