Proposal for IEEE 802.16m UL Control Structures

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Re: IEEE 802.16m-08/016r1 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "UL Control Structures"

Purpose: Adopt the proposal into the IEEE 802.16m System Description Document

Scope

- This contribution proposes an UL control structure for IEEE 802.16m
- The pilot design and HARQ protocol and timing are presented in separate contributions (see C802.16m-08/348 “Proposal for IEEE 802.16m UL Pilot Design” and C802.16m-08/353 “Proposal for IEEE 802.16m HARQ Protocol and Timing”).

IEEE 802.16m System Requirements

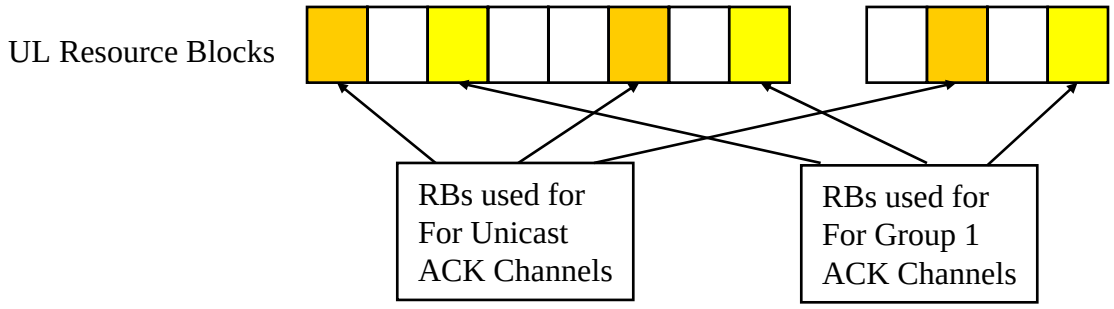
- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 6.10 System Overhead
    - “Overhead, including overhead for control signaling as well as overhead related to bearer data transfer, for all applications shall be reduced as far as feasible without compromising overall performance and ensuring proper support of systems features”
- The proposed UL control structure targets the above requirement.

Overview

- UL control channels are used for
  - ACK channel for acknowledging DL traffic
  - CQI feedback channel (broadband CQI and/or sub-band CQI)
  - Pre-coding matrix feedback channel (PMI)
  - Rank feedback
  - Best beam feedback
  - UL access channel (bandwidth request)
- In order to support the above feedback information, some resources must be allocated for UL control.
- The band is divided into resources blocks (RB)
  - The size of each resource block (RB) is 12 sub-carriers and 6 OFDM symbols (see contribution C802.16m-08/350).
  - The RBs used by the different UL control channels are spread over the entire band
  - Three RBs are used to form one basic channel unit (BCU), which is used for data.
  - The total number of resources used by all the UL control channels is in units of BCUs

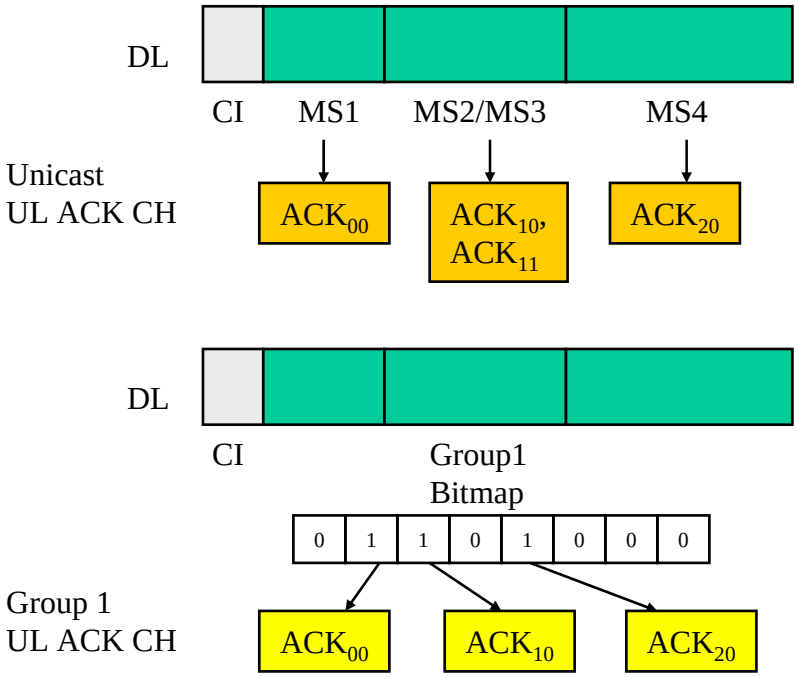
UL ACK Channel (1/3)

- One set of ACK channels is defined for all unicast transmission for the corresponding DL sub-frame.
- In the case of a TDD system where there are more DL sub-frames than UL sub-frames, a separate set of ACK channels is required for each corresponding DL sub-frame.
- A separate set of ACK channels is defined for each group in the case of group assignments.
- Each set of ACK channels are formed from resource blocks that are spread over the entire band.
- The number of ACK channels per set and the number of sets of ACK channels is configurable and is signaled in the superframe control. The number of sets of ACK channels on each sub-frame can also be deduced from the HARQ system parameters signaled to the MS including ACK delay, retransmission delay, number of HARQ interlaces (or channels). See contribution C802.16m-08/353 “Proposal for IEEE 802.16m HARQ Protocol and Timing”
- In addition, the superframe control channel contains the number of resources that is used for UL control. A permutation index (PI) that indicates how the resources are distributed to the different types of control channels



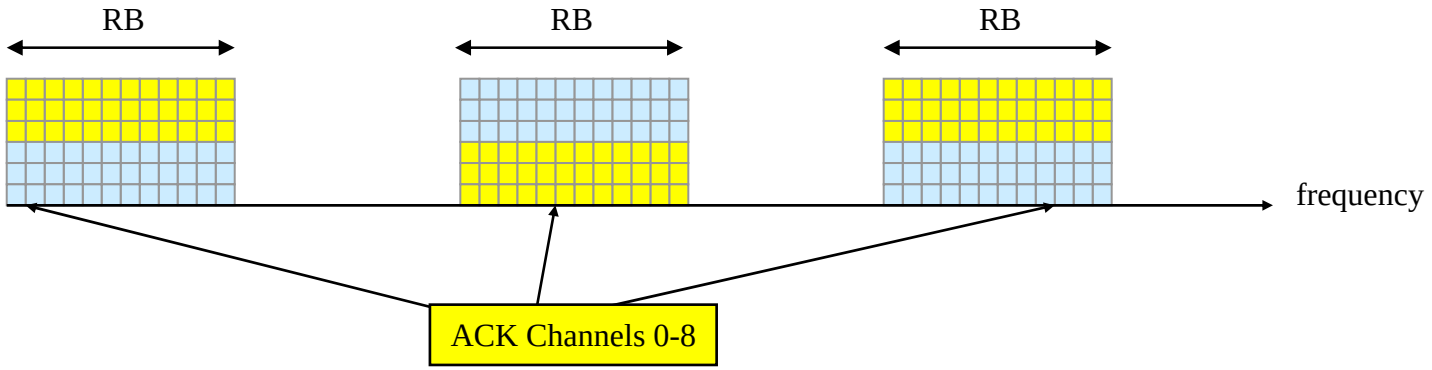
UL ACK Channel (2/3)

- For DL unicast transmission, the UL ACK channel corresponds to the DL partition number and the layer number.
  - A number of ACK channels are multiplexed onto the same ACK tile using orthogonal spreading codes.
- For DL group assignments, the UL ACK channel corresponds to the bit position in the bitmap.



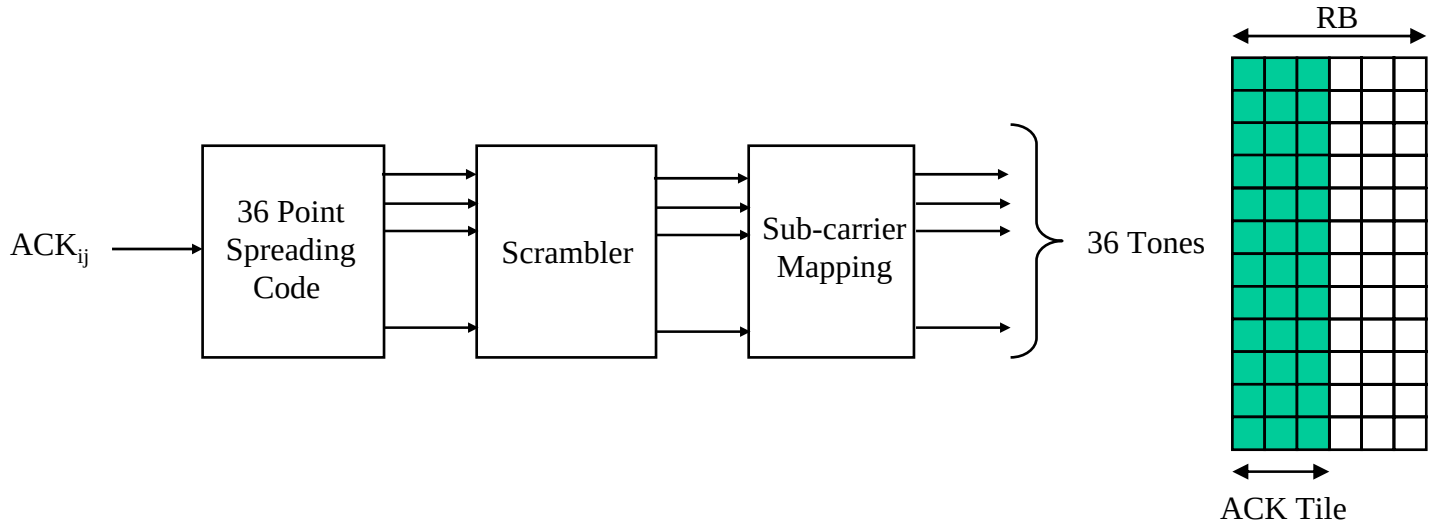
UL ACK Channel (3/3)

- Each ACK channel consists of 3 ACK tiles.
  - The ACK tiles hop over a number of resource blocks to obtain frequency diversity.
- The size of the ACK tile is 12 sub-carriers and 3 OFDM symbols. Other sizes are FFS.
- The value of the ACK is determined using non-coherent detection.
- One possible configuration of the ACK tiles is shown below.



UL ACK Channel Resource Assignment

- The UL ACK channel carries 3 states.
  - ‘1’ or ACK, to indicate that it has successfully decoded the corresponding DL sub-packet
  - ‘-1’ or NACK, to indicate that it has failed to decode the corresponding DL sub-packet
  - ‘0’ or null (no transmission on the ACK channel), when the MS does not receive any control signaling that indicates a sub-packet has been sent by the BS.
- The mobile sends the ACK value on ACK channel ACK_{ij}, which corresponds to the packet transmitted on partition *i* and layer *j*.
- Each ACK is spread over an ACK tile using a spreading code. For example, one column of a DFT matrix.
- The spreading is repeated on separate ACK tiles in order to obtain frequency diversity.
- The spreading code that is used is determined from a look-up table and corresponds to the partition and layer number for the DL assignment.



DFT Spreading Code Look-up Table

- The look-up table for the spreading code depends on the number of resources that are used for the ACK channels.
- The table below shows the look-up table for the spreading code when there are 9 ACK channels allocated (ACK tile size = 36 tones).
- Although there are 36 different spreading codes, only a maximum of 9 are used.
- If the number of packets transmitted on the DL does not exceed 9, the base station can configure three ACK tiles for the ACKs (ACK diversity order is 3).
- If more DL assignments are required, more resources are required.

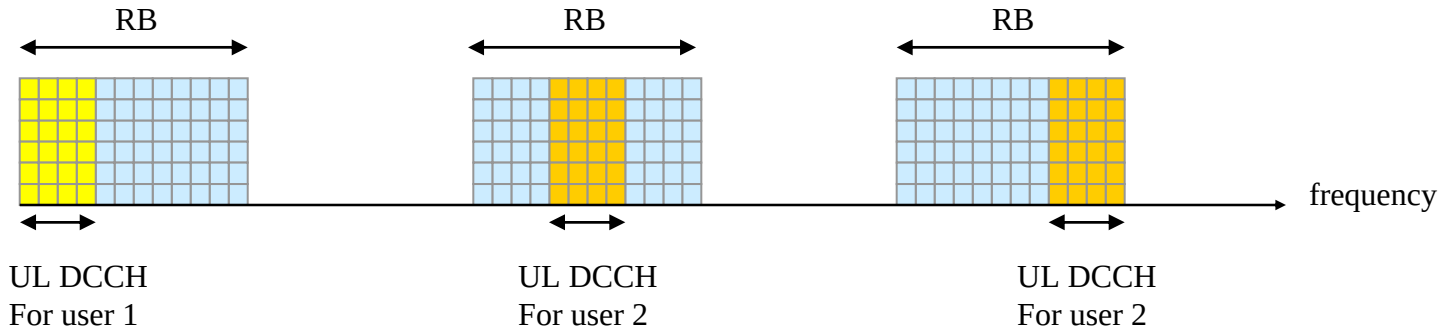
Partition	Layer 0	Layer 1	Layer 2	Layer 3
0	C0	C1	C2	C3
1	C4	C5	C6	C7
2	C8	C9	C10	C11
3	C12	C13	C14	C15
4	C16	C17	C18	C19
5	C20	C21	C22	C23
6	C24	C25	C26	C27
7	C28	C29	C30	C31
8	C32	C33	C34	C35

UL Dedicated Control Channel (1/2)

- The UL dedicated control channel is a periodic channel that is used for both periodic feedback and event driven feedback. It can include the following information
  - Broadband CQI feedback for diversity channel assignments
  - Sub-band CQI feedback for localized channel assignments
  - Pre-coding feedback for mobiles configured for CL MIMO
  - Rank feedback
  - BW request
- Since the channel is periodic, a fixed number of resources are dedicated for the UL control.
  - A fixed number of BCUs are used for all UL control channels
  - The control information is transmitted on UL control tiles that are formed from a fixed number of RBs that are spread over the entire band.
- In order to support both event driven and periodic feedback in one dedicated control channel, the content of the channel can change each feedback instance.
- The content of the message is indicated by a message type field.
- For example, if a mobile is configured to feedback sub-band CQI for 5 best bands then in order to send a BW request it can send a different message that includes the BW request.

UL Dedicated Control Channel (2/2)

- Dedicated UL control channels are formed from UL control tiles
  - The size of the UL control tile is 4 sub-carriers and 6 OFDM symbols. Other sizes are FFS.
  - The number of UL control tiles used depends on the MS configuration
  - If more than one UL control tile is assigned then the tiles are distributed over the band to obtain frequency diversity.
  - The pilot design depends on the number of UL tiles used by the MS (see contribution C802.16m-08/348).
  - The MS maps the required feedback information bits on the assigned control tiles using the assigned MCS (e.g. QPSK 1/3).



Contents of UL Dedicated Control Channel

- The UL dedicated control channel contains the following
  - CQI feedback (4-5 bits)
  - If CL MIMO is enabled
    - Pre-coding feedback (3-6 bits)
    - Rank feedback (2 bits)
  - If SDMA is enabled
    - Best beam feedback
  - If frequency selective scheduling is enabled
    - Sub-band CQI feedback (4-5 bits per sub-band)
- The number of control tiles allocated and the frequency of the feedback depends on the amount of information that is fed back.
- The content can be changed each feedback instance in order to accommodate different feedback intervals for different types of feedback.
  - For example, if the rank is fed back, the CQI feedback can be replaced by the rank.
- The UL dedicated control channel is scrambled by
  - The serving sector ID and
  - The user ID

Overhead Reduction for CQI Feedback

- The feedback overhead is the highest for the CL MIMO case.
  - Feedback is required per sub-band.
  - Both CQI and PMI are required for codebook based pre-coding feedback
  - If sounding is used instead of PMI feedback then the overhead is higher since both CQI and sounding information are required.
- In order to reduce the overhead for the case when sounding is used, a low rate feedback of an average interference value can be sent instead of the CQI per sub-band.
- The BS can determine the C/I from the channel sounding information and the average interference fed back from the MS.
- In the case of multi-codeword MIMO, the BS can also determine what the degradation of the C/I is for each layer assigned from the channel sounding and interference value.

UL Control Overhead (1/2)

- Assumptions
  - UL control tile size is 4 sub-carriers by 6 OFDM symbols
  - Number of pilot tones per tile = 4 per antenna
  - Number of transmit antennas at the MS = 2
  - CQI feedback = 4 bits
  - PMI feedback = 3 bits
  - CRC = 9 bits
  - The information is transmitted using QPSK 1/3

Number of CQICH	Total Bits	Total Symbols	Number of Control Tiles
1	13	19.5	2
2	17	25.5	2
3	21	31.5	2
4	25	37.5	3
5	29	43.5	3
6	33	49.5	4
7	37	55.5	4
8	41	61.5	4
9	45	67.5	5
10	49	73.5	5
11	53	79.5	5
12	57	85.5	6

Number of CQICH + PMI	Total Bits	Total Symbols	Number of Control Tiles
1	16	24	2
2	23	34.5	3
3	30	45	3
4	37	55.5	4
5	44	66	5
6	51	76.5	5
7	58	87	6
8	65	97.5	7
9	72	108	7
10	79	118.5	8
11	86	129	9
12	93	139.5	9

UL Control Overhead (2/2)

- The UL control overhead percentage is given in the table below for different number of users per sub-frame.
- Three cases are considered
  - Case 1: The MS sends only one CQI, 2 tiles are required.
  - Case 2: The MS sends a CQI value for 5 best bands, 3 tiles are required.
  - Case 3: The MS sends a CQI and PMI for 5 best bands, 5 tiles are required.
- If there are 8 mobiles per sub-frame (VoIP capacity for a 10 MHz TDD system), the UL control overhead for Case 1 is 7.4%

Number of Users	Number of Tiles	Total Control Tiles	Overhead (%)	Number of Tiles	Total Control Tiles	Overhead (%)	Number of Tiles	Total Control Tiles	Overhead (%)
1	2	2	0.93%	3	3	1.39%	5	5	2.31%
2	2	4	1.85%	3	6	2.78%	5	10	4.63%
3	2	6	2.78%	3	9	4.17%	5	15	6.94%
4	2	8	3.70%	3	12	5.56%	5	20	9.26%
5	2	10	4.63%	3	15	6.94%	5	25	11.57%
6	2	12	5.56%	3	18	8.33%	5	30	13.89%
7	2	14	6.48%	3	21	9.72%	5	35	16.20%
8	2	16	7.41%	3	24	11.11%	5	40	18.52%
9	2	18	8.33%	3	27	12.50%	5	45	20.83%
10	2	20	9.26%	3	30	13.89%	5	50	23.15%
11	2	22	10.19%	3	33	15.28%	5	55	25.46%
12	2	24	11.11%	3	36	16.67%	5	60	27.78%

Summary

- The proposed UL control structure satisfies the requirements of the TGm SRD.
- The new UL control structure design efficiently supports all UL control.

Proposed Text for SDD

- Section 11.x UL Control Structure
  - [*Add content of slide 4 to this section*]
- Section 11.x.1 UL ACK Channel
  - [*Add figure on slides 5 – 9 to this section*]
- Section 11.x.2 UL Dedicated Control Channel
  - [*Add content on slides 10 – 12 to this section*]