Proposal for IEEE 802.16m HARQ Protocol and Timing

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*<http://standards.ieee.org/faqs/affiliationFAQ.html>

Re: IEEE 802.16m-08/016r1 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "HARQ (Protocol and Timing)"

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

Introduction

- This contribution discusses and proposes different aspects of the HARQ protocol, timing and operation, including
  - Different types of HARQ schemes
  - Chase combining versus Incremental redundancy
  - Resource adaptive synchronous HARQ signaling
  - Resource adaptive synchronous HARQ operation
  - HARQ protocol timing and interlace structure for synchronous HARQ and resource adaptive synchronous HARQ

IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 6.2.1 Data latency:
    - As shown in Table 3, the maximum allowable latency for DL and UL is 10ms
  - 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 HARQ protocol and timing targets the above requirements

Different Types of HARQ

- There are several ways to perform retransmission in terms of the time interval, the resource location and the MCS

	Synchronous HARQ	**Asynchronous HARQ**	**Resource adaptive synchronous HARQ**
Retransmission time interval	Fixed/ predetermined	Variable, dynamically scheduled	Fixed/predetermined
Resource location	Same as first sub-packet transmission	Variable, dynamically assigned	Variable, dynamically assigned
MCS	Same for Chase, different for IR	Same for Chase, different for IR	Same for Chase, different for IR

Pros/Cons of Different Types of HARQ

	Synchronous HARQ	**Asynchronous HARQ**	**Resource adaptive synchronous HARQ (RAS-HARQ)**
Pros	Minimum signaling overhead as retransmission does not need to be signaled	Most flexible in terms of prioritization new transmission vs. retransmission. Provide better link adaptation / time diversity performance for very low speed case. If MS misses the control signaling of the first or any other sub-packet, there is still possibility to recover the packet.	Relative small signaling overhead compared to the async HARQ Flexible resource allocation and multiplexing among users.
Cons	Inflexible resource allocation and multiplexing. If MS misses the control signaling of first sub-packet and BS does not recognize that, it is not possible to recover the packet. In case of ACK to NAK error in the DL for UL transmission, MS' retransmission may collide with other MS.	Require most signaling overhead compared to the other two schemes in order to indicate ACID, sub-packet ID, AI-SN	If MS misses the control signaling of first transmission and BS does not recognize that, it is not possible to recover the packet.

We recommend resource adaptive synchronous HARQ as the baseline. Asynchronous HARQ can be used for error recovery and as needed basis at BS' discretion. Synchronous HARQ is used for the case of persistent allocation for VoIP.

Chase versus Incremental Redundancy

- Incremental redundancy (IR) provides both soft combining gain as well as coding gain. It is generally recommended.
- The additional signaling overhead of IR can be avoided by defining a sub-packet format lookup table.
  - For each MCS entry, the sub-packet format, i.e. modulation and effective coding rate derived from the mother code, is specified for each retransmission trial
- Some entries in the lookup table can be effectively reduced to Chase when two consecutive retransmission trials have the same sub-packet format.

Resource Adaptive Synchronous HARQ Signaling – 1/2

- In RAS-HARQ, only the resource location needs to be signaled for retransmissions
- There can be multiple parallel HARQ processes in progress for the same MS, where each HARQ process corresponds to first transmission and retransmissions of an encoder packet. Therefore the retransmission signaling needs to uniquely identity the corresponding HARQ process (or encoder packet ID) as well as the resource assigned for the retransmission.
- Required control information for retransmission:
  - Encoder packet ID to uniquely identify an encoder packet (thus the HARQ process)
  - Resource assignment information for the retransmission
  - The above signaling information is scrambled by the user ID of the MS
  - Correspondingly, the control information for the first sub-packet transmission also needs to include the encoder packet ID

Resource Adaptive Synchronous HARQ Signaling – 2/2

- The overall sub-frame control structure is presented in C802.16m-08/176 “Proposal for IEEE 802.16m Resource Allocation and Control Structure” in Session #54. The ordered list of available resources in a zone (diversity or localized) are divided into several segments, including
  - An UL control segment,
  - DL Unicast control and traffic segment(s),
  - DL Group control and traffic segment(s).
- As shown in the figure below, the unicast control information within the “DL unicast control and traffic” segment, and within the ‘UL control’ segment include the control information as described in the previous slide, for first sub-packet transmission and retransmissions.

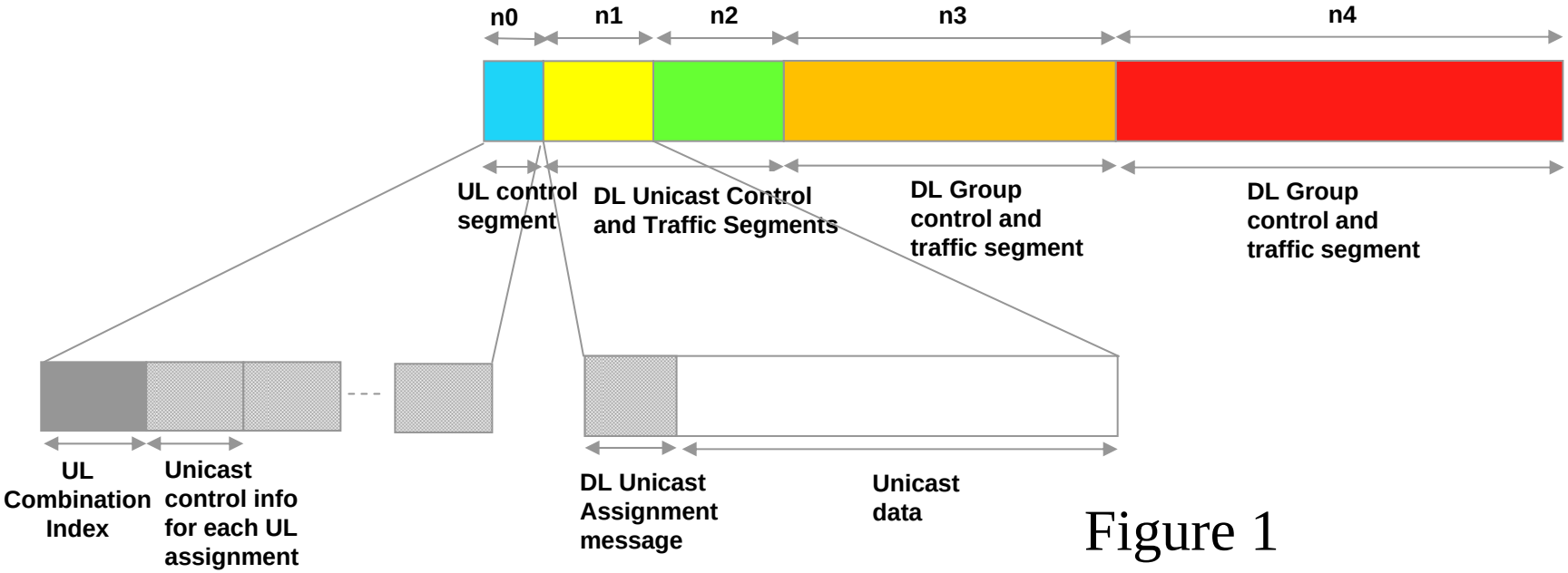

Figure 1

Resource Adaptive HARQ Operation – DL (1/2)

- A 3-state ACK channel (ACKCH) is used
  - ACK: to indicate correct reception of a packet
  - NAK: to indicate failure in reception of a packet
  - Null: no signal is transmitted by MS on the ACKCH. This occurs when MS fails to detect the control signaling corresponding to a sub-packet transmission.
- MS operation:
  - MS sends a NAK when it fails to decode a packet.
  - MS sends an ACK when it succeeds in decoding a packet
  - After sending a NAK, if the MS does not receive any retransmission signaling at the predetermined time interval, there can be two possibilities:
    - 1) MS fails to detect the retransmission signaling. This can be recovered by the BS after detecting a ‘null’ from the MS, as described in the next slide.
    - 2) BS does not send retransmission due to NAK-to-ACK detection error at the BS. In this case, a packet failure will occur.
  - MS retains the HARQ buffer corresponding to an encoder packet until a configurable timeout period.

Resource Adaptive HARQ Operation – DL (2/2)

- BS operation:
  - When the BS receives a NAK from an MS, the BS retransmits a sub-packet to the MS at a predetermined time interval. New resource location and encoder packet ID, user ID (scrambled) is signaled as described in slide 7.
  - When the BS receives an ACK from an MS, the BS does not perform retransmission to the MS
  - When the BS receives a null from an MS, the BS will interpret that the MS has lost the signaling associated with a sub-packet transmission. There are two cases:
    - If it was the first sub-packet transmission, the BS will retransmit the first sub-packet in conjunction with the full signaling information, i.e. MCS, resource location, user ID (scrambled), MIMO information, packet ID etc. BS can dynamically schedule the retransmission of this first sub-packet at any time.
    - If it was second or higher sub-packet transmission, the BS will retransmit at the predetermined time interval the corresponding sub-packet in conjunction with control signaling for retransmission as described in slide 7.

Resource Adaptive HARQ Operation – UL

- BS operation:
  - When BS fails to receive a packet, it schedules an UL retransmission of the sub-packet at the predetermined time interval. New resource location, HARQ encoder packet ID user ID (scrambled) is signaled as described in slide 7.
  - When BS succeeds in decoding a packet, no retransmission is scheduled.
  - BS performs the following error recovery procedure for the case when MS fails to decode the first sub-packet transmission signaling or the subsequent retransmission signaling:
    - For the case of first sub-packet transmission signaling, if the BS fails to detect any UL transmission from the MS at the assigned resource, the BS can resend the full signaling information, i.e. MCS, resource location, user ID (scrambled), MIMO information etc. BS can dynamically schedule the retransmission of this first sub-packet at any time.
    - For the case of retransmission signaling, if the BS fails to detect any UL transmission from the MS at the assigned resource, the BS can send at the predetermined time interval the control signaling for retransmission as described in slide 7
- MS operation:
  - When MS receives the retransmission signaling from the BS, the MS transmits the corresponding sub-packet in the assigned resource.
  - MS retains the HARQ buffer corresponding to an encoder packet until a configurable timeout period.

HARQ Timing

- The HARQ protocol timing should be flexible to adapt to different TDD ratio and 16m/legacy partitioning, without incurring unnecessary overhead.
- The minimum HARQ ACK and Retrx delay and the number of HARQ channels/interfaces are defined in system/MS configuration signaling which corresponds to particular partitioning of legacy and 16m, and TDD ratios. With these parameters defined, the precise HARQ timing for ACK/NAK transmission and retransmission can be deduced (refer to Figures 2-6 in next few slides). This is applicable to both TDD and FDD.
- Due to the asymmetrical DL/UL TDD ratio, the UL acknowledgement of DL HARQ for multiple DL sub-frames may co-inside in one UL sub-frame as shown in Figures 3 and 4. The location of the ACKCH of an MS within the UL sub-frame can be deduced from the HARQ interlace number, the assigned DL resource of the previous HARQ sub-packet transmission, and the number of UL ACKCHs allocated per DL sub-frames as signaled in the superframe header. Similar approach is used for the case of DL acknowledgement of UL HARQ as shown in Figure 6.
- Details of ACKCH design is described in IEEE C802.16m-08/351 “Proposal for IEEE 802.16m UL Control Structures”.

DL HARQ Timing – 1/2

Example 1: 16m TDD ratio of 2:3 (minimum ACK delay and Retrx delay are 4 sub-frames, 2 HARQ interlaces, as configured by the BS)

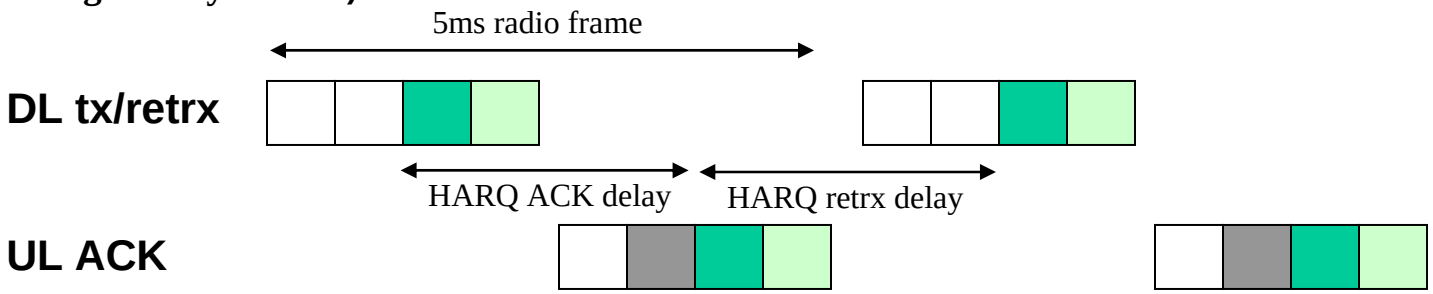

Figure 2

Example 2: 16m TDD ratio of 3:2 (minimum ACK delay and Retrx delay are 4 sub-frames, 4 HARQ interlaces as configured by the BS).

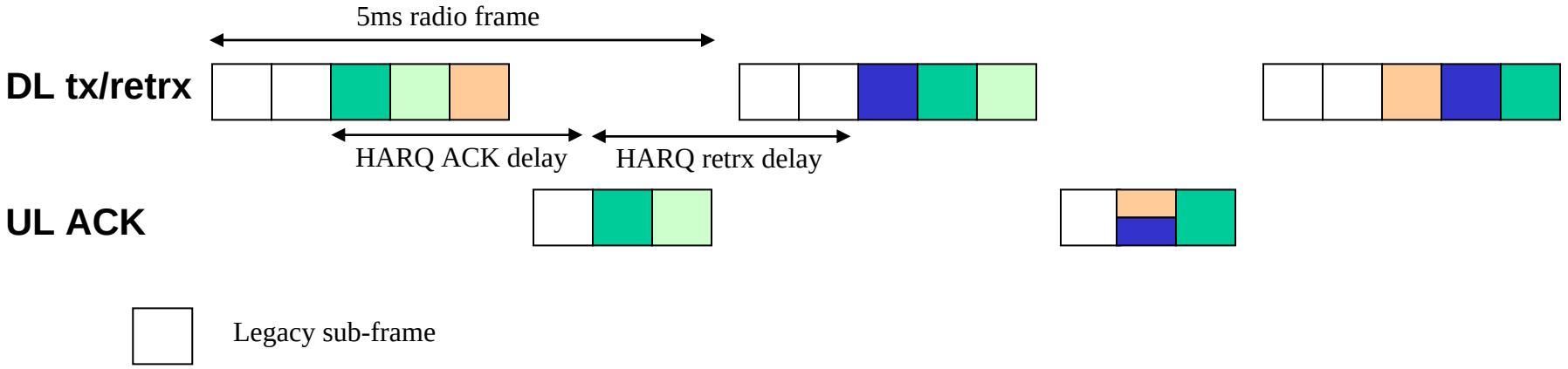

Figure 3

DL HARQ Timing – 2/2

Example 5: 16m TDD ratio of 5:3 (minimum ACK delay and Retrx delay are 4 sub-frames, 7 HARQ interlaces , configured by the BS)

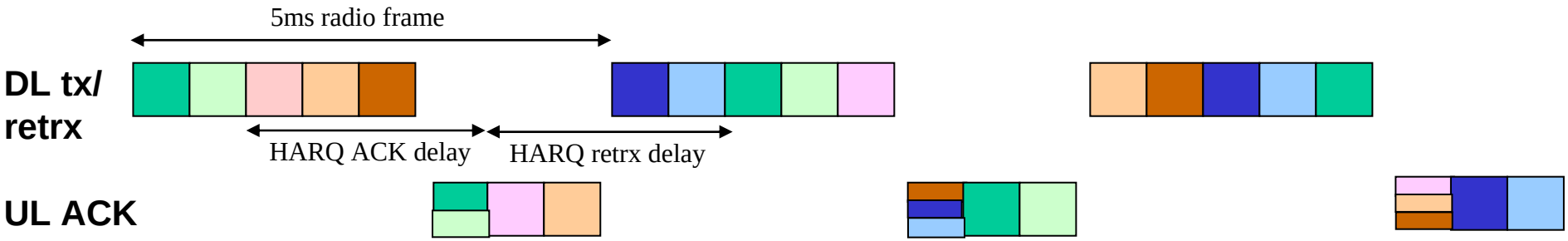

Figure 4

UL HARQ Timing

Example 1: 16m TDD ratio of 3:2 (ACK delay and Retrx delay are 4 sub-frames, 2 HARQ interlaces, as configured by the BS)

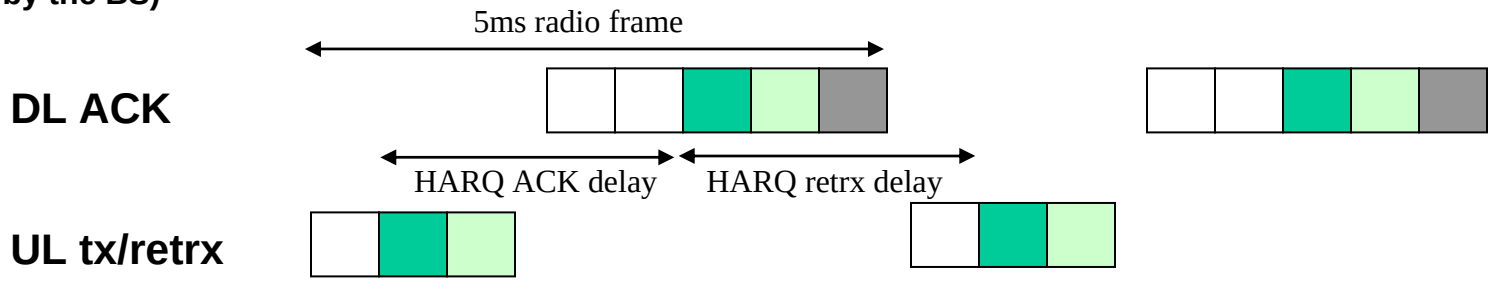

Figure 5

Example 2: 16m TDD ratio of 2:3 (ACK delay and Retrx delay are 4 sub-frames, 4 HARQ interlaces, as configured by the BS)

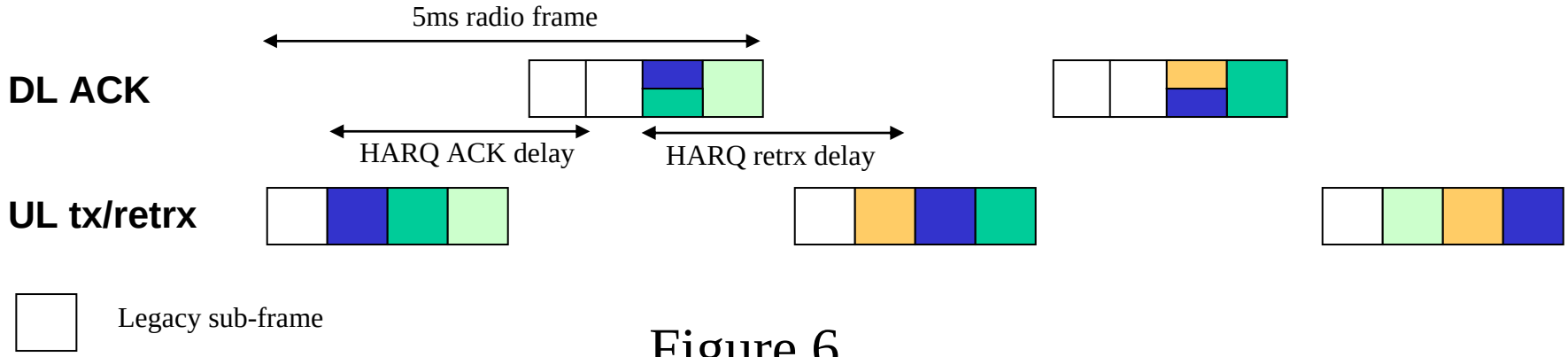

Figure 6

Proposed Text for SDD

- Section 11.x: HARQ Protocol and Timing
- Section 11.x.1 Types of HARQ schemes
  - [*copy content of slide 4 to here*]
  - Resource adaptive synchronous HARQ is used as the baseline HARQ operation. Asynchronous HARQ is used for error recovery and as needed basis at BS' discretion. Synchronous HARQ is used for the case of persistent allocation for VoIP.
- Section 11.x.2 HARQ soft combining techniques
  - [*copy content of slide 6 here*]
- Section 11.x.3 Resource adaptive synchronous HARQ signaling
  - [*copy content of slides 7, 8 here*]
- Section 11.x.4 Resource adaptive synchronous HARQ operation
  - [*copy content of slides 9-11 here*]
- Section 11.x.5 HARQ protocol timing and interlace structure for synchronous HARQ and resource adaptive synchronous HARQ
  - [*copy content of slides 12-15 here*]