Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Centralized HARQ Retransmission Handling for Non-Transparent RS
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Re:	This document is in response to call for technical proposals IEEE 802.16j-07/007r2 dated 19 February 2007. This document proposes text regarding signaling for efficient routing for insertion in baseline document IEEE 80216j-06/026r2.
Abstract	Several methods for centralized scheduling of HARQ retransmission attempts are discussed and proposed.
Purpose	Adoption of the proposed text into P802.16j
Notice	
Release	
Patent Policy and Procedures	

Proposal for Centralized HARQ Retransmission Scheduling for Non-Transparent RS

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1 Introduction

This contribution is concerned with scheduling of HARQ retransmission attempts on a multihop path in an MR system. This contribution focuses on the centralized scheduling approach for non-transparent RS, with burst allocations for all hops performed mainly at the MR-BS and with limited scheduling performed at the RS, if necessary. The contribution proposes both the DL and UL HARQ retransmission scheduling strategies. The proposed strategies support a per-hop multi-channel stop-and-wait HARQ protocol, with retransmissions performed only on hops where previous transmission attempts have failed. These retransmission strategies in general are not tied to a specific HARQ ACK/NAK feedback scheme, nor are they tied to a specific method of scheduling initial HARQ transmission attempts. Nevertheless, this proposal fully supports and is compatible with the DL and UL ACK/NACK reporting schemes proposed in 6 and 6, as well as proposed therein scheme to schedule initial HARQ attempts. In this contribution, three retransmission scheduling strategies are proposed, namely explicit scheduling, pre-scheduling, and implicit scheduling. The first strategy is applicable on any hop of the multihop path, whereas the latter two are proposed for the access link hop.

2 Explicit Scheduling of HARQ Retransmissions

2.1 Explicit DL Scheduling of HARQ Retransmissions

It is assumed that all DL HARQ transmission attempts are scheduled at the MR-BS. As proposed in 6, MR-BS schedules in advance burst allocations for the initial DL transmission attempts on the multihop path, assuming successful decoding of the initial transmission attempts on the preceding hops. This initial attempt schedule spans multiple frames in time, taking into account the decoding delays and other timing constraints at the intermediate RSs along the path. Each RS is informed of its HARQ burst allocations via the legacy HARQ DL MAP IE as defined in the IEEE 802.16e-2005 specification, Section 8.4.5.3.21. The precise method used to deliver this IE to an RS is outside the scope of this contribution. As a possibility, this IE could be delivered to an RS as part of a MAC management message sent from the MR-BS. A HARQ DL MAP IE received at an RS in frame i, is applicable in frame i d, where d denotes the IE scheduling delay at an RS and is a minimum of one frame. This IE scheduling delay is a system parameter announced to an RS as part of control messaging. Following the IE scheduling delay, in frame i d, the HARQ DL MAP IE is included in the DL R-MAP for a downstream RS, or it is included in the legacy DL-MAP in the access interval if intended for the MS.

The proposed scheduling scheme applies to paths with arbitrary number of hops. As an example, consider a three-hop path as shown in Figure 1. The corresponding bounce diagram is shown in Figure 2. In the figure, evolution of a single HARQ channel of a multihop flow is shown. In general, the scheme supports multiple parallel channels enabling a multi-channel stop-and-wait HARQ protocol. For this example, a decoding delay of one frame per hop and an ACK/NACK forwarding delay of one frame per hop are assumed. Furthermore,

In the example of Figure 2, a HARQ DL MAP IE applies one frame later after it is received at the intended RS. That is, an IE scheduling delay of one frame is assumed. Furthermore, to simplify the figure, a decoding delay of *zero* frames at an intermediate RS is assumed for the MAC management messages carrying HARQ DL MAP IEs. This is in contrast to the assumption of one frame decoding delay for the data packets. It is also reasonable to assume that the MAC management message and data decoding delays are the same. In that case, the data bursts and the accompanying HARQ DL MAP IEs to schedule subsequent bursts on downstream hops need to be transmitted in the same frame. For brevity, a bounce diagram for this case is omitted.

As shown in Figure 2, the initial transmission attempt is scheduled in advance on all hops, allowing for the one frame decoding delays at the intermediate RSs. In this example, the initial transmission on the second hop in frame 3 has failed. Assuming a synchronous HARQ feedback scheme proposed in 6, the UL HARQ feedback region is allocated in the frame $i \quad n$ at an RS for a HARQ burst received in frame i, where $n \quad h \quad p \quad h \quad 1 \quad j$, h is the number of hops from the RS to the MS, p is the processing delay at the intermediate relay, equal in this case to the transmission delay of one frame, and j is the HARQ_ACK_Delay for DL burst, equal in this case to the decoding delay plus the ACK/NACK delay of one frame. Upon receiving a NACK in frame 9 identifying failure on the second hop, MR-BS schedules the retransmission in frame 11, allowing for the IE scheduling delay of one frame at RS1. Furthermore, the initial transmission attempt on the access link is scheduled in advance, assuming successful decoding of the second transmission attempt at RS2.

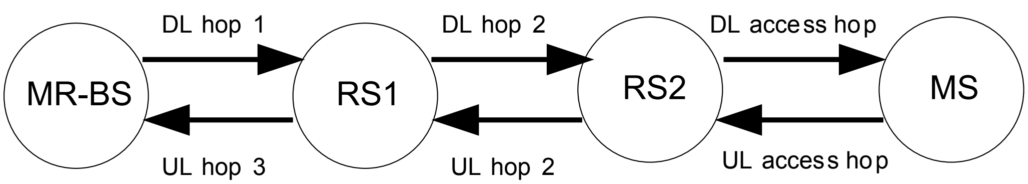

Figure 1. Example topology

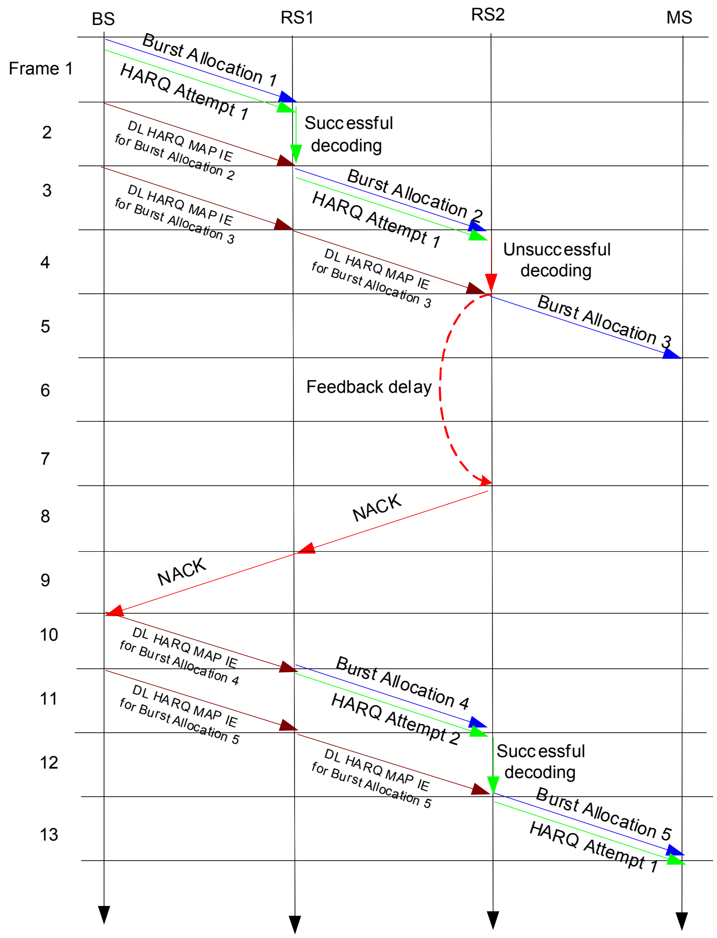

Figure 2. Example of DL explicit scheduling approach.

2.2 Explicit UL Scheduling of HARQ Retransmissions

The explicit scheduling of HARQ retransmissions on the UL follows the same strategy as on the DL. That is, the initial transmission attempt is scheduled in advance on all hops between an MS and MR-BS. All UL burst allocations are signaled to the RSs from the MR-BS via the HARQ UL MAP IE. After a fixed IE scheduling delay, this IE is signaled from the upstream RS to a downstream RS in the UL R-MAP in the relay interval, or it is signaled to an MS from its access RS in the access UL-MAP. Assuming the UL HARQ feedback scheme proposed in 6, ACK/NACK feedback for a failed UL HARQ burst is provided to the MR-BS via UL ACK channel in the form of encoded NACK.. This encoded NACK provides information about the link where the transmission for burst is failed. The transmitting RS obtains feedback from the receiving RS regarding UL HARQ bursts via the legacy HARQ-MAP IE. Retransmissions are scheduled on the failed hop and onwards, where transmissions on subsequent hops are scheduled in advance, assuming successful transmissions on the preceding hops.

3 Pre-scheduling of HARQ Retransmissions on the Access Link

3.1 Pre-scheduling of DL HARQ Retransmissions on the Access Link

As evident in Figure 2, the explicit scheduling scheme leads to substantial packet completion delays, particularly in the case of decoding failure on the access link. For instance, assuming in Figure 2 that the initial transmission attempt on the access link fails in frame 5, the second transmission attempt on that link will be performed only in frame 12. Note, however, that with a smaller intermediate RS decoding delay, the second transmission attempt could be performed sooner. For instance, assuming a zero frame decoding delay at an intermediate RS, the initial transmission attempt will be performed in frame 3, and the retransmission attempt will be performed in frame 9. In any case, such a retransmission delay could be detrimental to the performance of voice or other delay-sensitive applications in an MMR network. To reduce packet completion delays arising due to failures on the access link, a pre-scheduling strategy for HARQ retransmissions on the access link is proposed.

Continuing with the topology in Figure 1, a bounce diagram showing pre-scheduling as applied on the DL access link is shown in Figure 3. In this case, MR-BS provides an allocation to RS2 for a retransmission attempt on the access link in advance, *assuming a decoding failure on the initial transmission attempt*. This pre-scheduling strategy enables the MR-BS to enact the second retransmission attempt without waiting for the ACK/NAK feedback from the MS, thereby significantly reducing packet completion latency. The second HARQ attempt is utilized by an RS only if necessary, based on the ACK/NACK feedback provided to it by the MS in the UL access zone. If the second transmission attempt has been allocated, but is not necessary, the RS may optionally utilize this allocation for other purposes, such as forwarding high priority traffic or control messages to one of the MS under its coverage. Such flexibility requires the RS to perform limited autonomous scheduling. If the RS lacks autonomous scheduling capability, it will remain silent during the pre-scheduled retransmission attempt. In general, an arbitrary number of retransmission attempts can be pre-scheduled.

The number of pre-scheduled retransmission attempts depends on the prevailing channel conditions on the access link, such as average signal-to-noise plus interference ratio or average packet error rate. The algorithm to determine the number of pre-scheduled retransmission attempts is not specified. CQI feedback provided from the MS to the MR-BS for centralized scheduling and link adaptation could be also used as input to the retransmission pre-scheduling algorithm.

Pre-scheduled HARQ attempts are signaled to the access RS from the MR-BS via the legacy HARQ DL MAP IE. The number of pre-scheduled attempts, as well as the type of HARQ retransmission scheduling policy enacted by the MR-BS for a given MS connection, is signaled to the access RS via the RS_HARQ_Config message. Prior to exhausting pre-scheduled HARQ retransmission attempts for a given HARQ channel, the access RS does not forward ACK/NACK feedback to the MR-BS, and MR-BS allocates an UL HARQ feedback region for the HARQ channel only following the last pre-scheduled retransmission attempt. If the access RS exhausts pre-scheduled retransmission attempts, it reverts to the explicit retransmission strategy and forwards a NACK to the MR-BS through the allocated UL HARQ feedback channel. On the other hand, if the access RS is successful in delivering the packet to the MS during one of the pre-scheduled retransmission attempts, it will forward an ACK through the allocated UL HARQ feedback channel. As noted above, this UL HARQ feedback channel is allocated only following all pre-scheduled retransmission attempts, and the access RS is only permitted to forward the ACK in the allocated feedback channel.

To preserve the synchronous nature of the 802.16e DL HARQ feedback scheme, only HARQ flows with the same number of pre-scheduled retransmission attempts are allowed to be jointly scheduled into the same HARQ region. Extending the coded DL HARQ feedback proposal in 6 to enable pre-scheduling, an UL HARQ feedback region is allocated in the frame $i \;\; n$ at an RS for a HARQ region received in frame i, where $n \;\; h \;\; p \;\; h \;\; 1 \;\; j \;\; p \;\; j \;\; k$, h is the number of hops from the RS to the MS, p is the static processing delay at the intermediate relay, equal in this case to the transmission delay of one frame, j is the HARQ_ACK_Delay for DL burst, equal in this case to the decoding delay plus the ACK/NACK delay of one frame, and k is the number of prescheduled retransmissions attempts for a HARQ flow. Identifiers may be inserted in the HARQ DL MAP IE and HARQ ACK Region Allocation IE to identify a DL HARQ region with its corresponding UL HARQ feedback region.

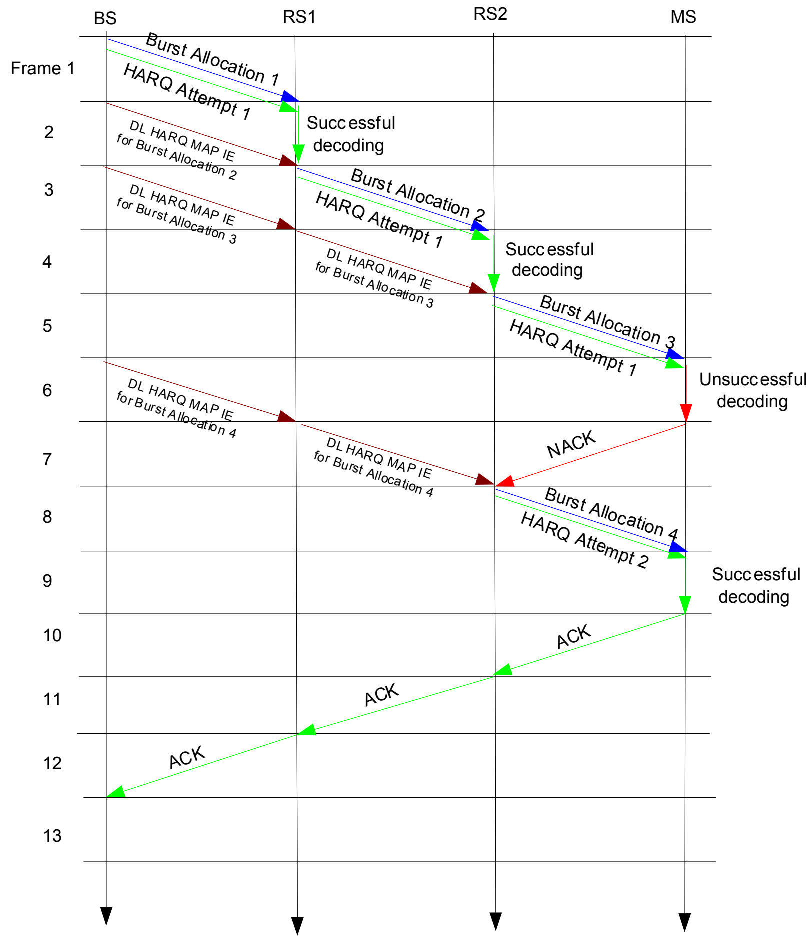

Figure 3. Example of DL pre-scheduling approach.

3.2 Pre-scheduling of UL HARQ Retransmissions on the Access Link

The pre-scheduling strategy for the UL is similar to the proposed retransmission pre-scheduling scheme on the DL. Following the Explicit UL Scheduling Proposal in Section 2.2, the initial transmission attempt on the UL access link is scheduled at the MR-BS and signaled to the access RS via the legacy HARQ UL MAP IE. The initial transmission attempts on subsequent upstream hops are allocated at the MR-BS in advance, assuming successful decoding of the initial transmission attempts on the preceding hops. All allocations are signaled to the intermediate RSs via the legacy HARQ UL MAP IE. To reduce HARQ retransmission latency on the access link, several access link HARQ retransmission attempts are pre-scheduled by the MR-BS. For each pre-scheduled retransmission on the access link, allocations in advance on subsequent upstream hops are also made. For an example of an UL pre-scheduling strategy refer to Figure 4. In the figure, a repeat transmission attempt is pre-scheduled in frame 5 on the access link and corresponding allocations for HARQ attempts on the RS2-RS1 and RS1-BS links are made in frame 7 and frame 9, respectively. For this example, an IE scheduling delay of two frames on the UL is assumed.

If on the access link a packet is successfully received at the access RS prior to exhausting all pre-scheduled retransmission attempts, the access RS may utilize pre-scheduled allocations for other purposes, such as granting BW for other MS under its control. If on the access link a packet is not successfully received in the allotted number of transmission attempts, the access RS reverts to the explicit UL scheduling strategy. In this case, no explicit feedback is provided to the MR-BS regarding the state of the HARQ channel on the access link. This serves as a negative acknowledgement at the MR-BS, which may proceed to schedule another transmission attempt on the access link. In case of a decoding failure on an RS-to-RS or RS-to-MR-BS link, an RS follows the feedback scheme of 6 and transmits a encoded NACK via the UL ACK channel.

The specific retransmission strategy utilized on the access link for a given UL HARQ flow is signaled to the access RS via the RS_HARQ_Config message. This message also instructs the access RS as to the number of pre-scheduled retransmission attempts allowed on the access link for a given MS connection. The algorithm to compute the number of pre-scheduled retransmission attempts is unspecified, but could be based on the CQI feedback provided from the access RS to the MR-BS regarding the UL access link.

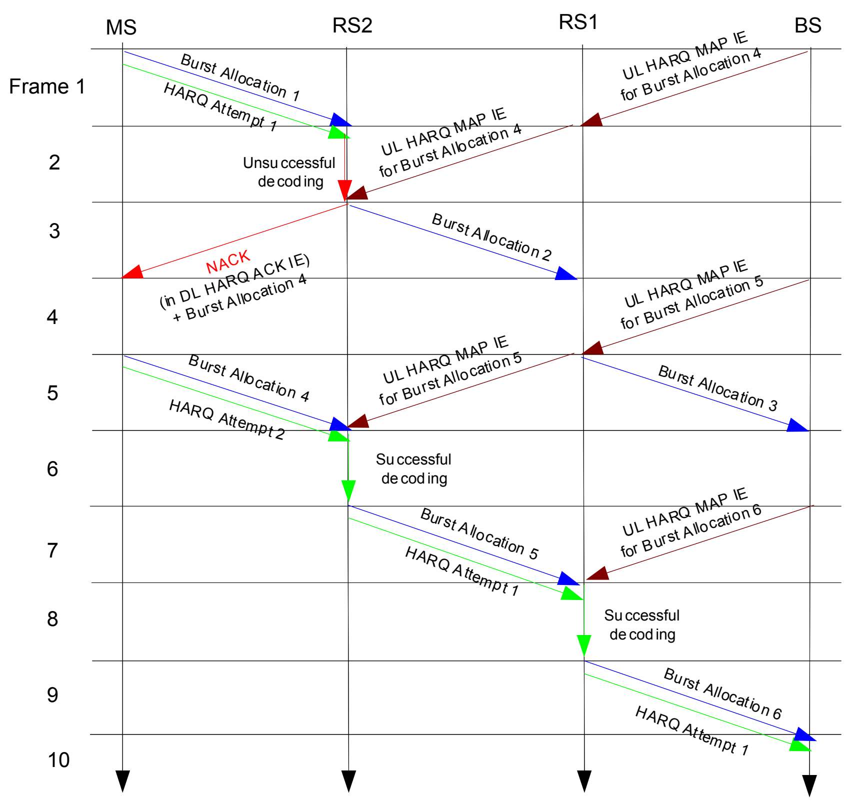

Figure 4. Example of UL pre-scheduling approach.

4 Implicit Scheduling of HARQ Retransmissions on the Access Link

4.1 Implicit Scheduling of DL HARQ Retransmissions on the Access Link

It is assumed that all DL HARQ transmission attempts are scheduled at the MR-BS. As proposed in 6, MR-BS schedules in advance burst allocations for the initial DL transmission attempts on the multihop path, assuming successful decoding of the initial transmission attempts on the preceding hops. This initial attempt schedule spans multiple frames in time, taking into account the decoding delays and other timing constraints at the intermediate RSs along the path. Each RS is informed of its HARQ burst allocations via the legacy HARQ DL MAP IE as defined in the IEEE 802.16e-2005 specification, Section 8.4.5.3.21.

In the implicit scheduling scheme, if a HARQ attempt fails on the access link, then the access RS assumes that the burst allocation for retransmission of the next HARQ attempt for the same HARQ sub-burst is reserved at the same position after N_DL_RETX_DELAY frames. The MR-BS will receive the encoded NACK following the first unsuccessful transmission attempt and therefore it will not schedule any data for that allocation. The value of N_DL_RETX_DELAY is larger than $n \; \mathrm{DL\_HARQ\_ACK\_DELA}$, where n is the number of hops between the MS and the MR-MS. The access RS will modify the HARQ DL MAP IE received from the MR-BS by explicitly creating the HARQ region for retransmitting the HARQ attempt.

If an initial HARQ attempt fails on relay links, then explicit scheduling of HARQ retransmission will be performed.

Implicit scheduling of HARQ retransmission on the access link will not require transmission of the HARQ DL MAP IE from the MR-BS to an access RS to enable retransmission attempts. Therefore this scheme is bandwidth efficient.

4.2 Implicit Scheduling of UL HARQ Retransmissions on the Access Link

The implicit scheduling scheme for the UL is similar to the proposed implicit scheduling scheme on the DL. Following the Explicit UL Scheduling Proposal in Section 2.2, the initial transmission attempt on the UL access link is scheduled at the MR-BS and signaled to the access RS via the legacy HARQ UL MAP IE. The initial transmission attempts on subsequent upstream hops are allocated at the MR-BS in advance, assuming successful decoding of the initial transmission attempts on the preceding hops. All allocations are signaled to the intermediate RSs via the legacy HARQ UL MAP IE.

In the implicit scheduling scheme, if a HARQ attempt fails on the access link, then the access RS assumes that burst allocation for retransmission of the HARQ attempt for the same HARQ sub-burst is reserved at same position after N_UL_RETX_DELAY frames. The MR-BS will receive a NACK following the first attempt and therefore it will not schedule any data for that allocation. The value of N_UL_RETX_DELAY is larger than $n \; \mathrm{DL\_HARQ\_ACK\_DELA}$, where n is the number of hops between MS and MR-MS. The access RS will modify the HARQ UL MAP IE by explicitly creating the HARQ region for retransmitting HARQ attempts.

If initial HARQ attempt fails on relay links, then explicit scheduling of HARQ retransmission will be performed.

Implicit scheduling of HARQ retransmission on the access link will not require transmission of HARQ UL MAP IE from MR-BS to the access RS to enable retransmission attempts. Therefore it is bandwidth efficient.

5 Proposed Text

[Insert the following text at the end of Section 6.3.17.5]

MR-BS may schedule multiple retransmissions in advance on the DL access links. The allocation of retransmissions is at the discretion of the MR-BS, but a retransmission may be scheduled no sooner than the preceding transmission plus "HARQ ACK Delay for DL Burst" on the DL access link. The number of pre-scheduled retransmissions for a HARQ flow may be provided to the access RS from the MR-BS in the RS HARQ Configuration message.

Implicit HARQ retransmission scheduling scheme may be applied on the DL access link. The implicit HARQ retransmission scheme shall be used only with Chase combining. In the implicit scheduling scheme, if a HARQ attempt fails on the access link, then the access RS assumes that the burst allocation for retransmission of the next HARQ attempt for the same HARQ sub-burst is reserved at the same position after N_DL_RETX_DELAY frames. The MR-BS will receive the encoded NACK following the first unsuccessful transmission attempt and therefore it will not schedule any data for that allocation.

[Insert the following text at the end of Section 6.3.17.6]

MR-BS may schedule multiple retransmissions in advance on the UL access links. The allocation of retransmissions is at the discretion of the MR-BS, but a retransmission may be scheduled no sooner than the preceding transmission plus “HARQ ACK Delay for UL Burst” on the UL access link. The number of pre-scheduled retransmissions for a HARQ flow shall be provided to the access RS in the RS HARQ Configuration message.

Implicit HARQ retransmission scheduling scheme may be applied on the UL access link. The implicit HARQ retransmission scheme shall be used only with Chase combining. In the implicit scheduling scheme, if a HARQ attempt fails on the access link, then the access RS assumes that the burst allocation for retransmission of the next HARQ attempt for the same HARQ sub-burst is reserved at the same position after N_UL_RETX_DELAY frames. The MR-BS will receive the encoded NACK following the first unsuccessful transmission attempt and therefore it will not schedule any data for that allocation.

[Insert new Section 6.3.2.3.AA]
6.3.2.3.AA RS HARQ Configuration (RS_HARQ_Config) message
The RS_HARQ_Config message generated at the MR-BS may specify to an access non-transparent RS a HARQ retransmission scheduling mode for HARQ flows through the RS. The RS_HARQ_Config message shall be transmitted on the access RS basic CID.

Syntax	Size	Notes
RS_HARQ_Config Message Format {		
Management Message Type=TBD	8 bits	
N_CID	4 bits	Number of MS CIDs to which this message refers
For (j=0; j<N_CID; j++){		
CID	16 bits	CID of a HARQ connection
HARQ retransmission mode	1 bit	0: Pre-scheduling 1: Implicit scheduling
If (HARQ retransmission mode == 0){		
N_attempts	3 bits	Number of prescheduled retransmissions
}		
}		
Padding	Variable	
}		

[Insert in the following text at the end of the sub-clause]
8.4.5.4.25 HARQ ACK Region Allocation IE
If pre-scheduling of retransmissions on the DL is enabled, only HARQ flows with the same number of pre-

scheduled retransmission attempts shall be scheduled into the same HARQ region. An UL HARQ feedback region is allocated in the frame $i \quad n$ at an RS for a HARQ region received in frame i, where

$$n \quad h \quad p \quad h \quad 1 \quad j \quad p \quad j \quad k,$$

h is the number of hops from the RS to the MS, p is the static delay, j denotes HARQ_ACK_Delay for a DL burst, and k is the number of prescheduled retransmissions attempts for a HARQ flow. Identifiers may be inserted in the HARQ DL MAP IE and HARQ ACK Region Allocation IE to identify a DL HARQ region with its corresponding UL HARQ feedback region.

6 References

C80216j-07_203, "DL HARQ for Non-Transparent RS".

C80216j-07_204, "UL HARQ for Non-Transparent RS".