Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**	
Title	**HARQ with Relays**	
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Re:	This is in response to the call for proposals 80216j-06_027.pdf	
Abstract	This contribution proposes a procedure for handling retransmission of HARQ failure attempts in a relay system.	
Purpose	Add proposed spec changes in P802.16j Baseline Document (IEEE 802.16j-06/026)	
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HARQ with Relays

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Problem Description

In single hop system, HARQ is performed directly between BS and MS. However, in the relay system, there could be one or more RSs between an MMR-BS and an MS. HARQ could be performed in the fashion of hop-by-hop (i.e., between every two adjacent stations - MS-RS2, RS2-RS1 and RS1-MMR-BS as shown in Figure 1).

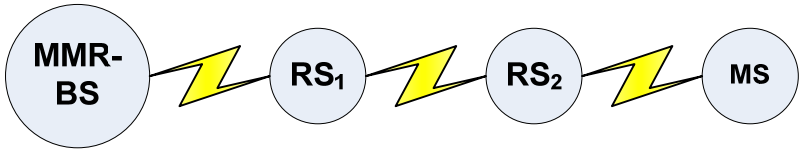

Figure 1: Illustration of Multi Hops in relay System

Both centralized and distributed MAP allocation mechanisms could be adopted in relay system. In centralized MAP allocation, the MMR-BS allocates MAP for all the links. Any need for bandwidth request should go to the MMR-BS. In distributed MAP allocation, each station allocates MAP for the adjacent link. In centralized allocation, if a HARQ packet transmission failure occurs on a non-adjacent link from MMR-BS, then a mechanism is needed for indicating this failure to the MMR-BS. So MMR-BS can grant bandwidth for retransmission on the effected links.

HARQ scheme with centralized scheduling

This contribution suggests a mechanism for indicating the last RS on the relay path that has successfully received the HARQ packet to MMR-BS. The indication is only sent when the last RS receives NAK from the next station in the relay path. It is not sent when a HARQ packet is successfully transmitted on all the hops. The MMR-BS uses this indication and allocates MAP accordingly so the retransmission could start from the last RS and onward.

This contribution is suggesting a mechanism that will work on any centralized MAP allocation scheme. It does not suggest a centralized MAP allocation scheme. It utilizes a bandwidth request mechanism proposed in [1].

Simulation Results

This section describes the comparison of proposed HARQ scheme and end-to-end HARQ scheme. Simulation is performed to analyze the gain in the spectral efficiency and PER with the proposed HARQ scheme. Following table shows the simulation parameters used in the simulation.

Scheduler	Round Robin (goes through HARQ Channels of MSs)	HARQ_DL_ACK_DELAY	1 frame
No of HARQ Channels scheduled per MS in one frame	2	HARQ_SCHED_DELAY	3 frames
No of MS in system	20	MAX_RETX_COUNT	4
No of HARQ Channels per MS	6	UL and DL overhead for resource request	10 bytes
Total HARQ Channels available in one frame	15	Resource Request latency at RS	3 frames
Frame Duration	5 ms	Queue Length at RS	variable
Simulation Duration	60000 frames	No of Hops	variable
Error generation	Uniform random error generation with BLER of 10 %	Flow control	supported

Table 1: Simulation parameters

It can be seen from the figure 2 that proposed scheme provides more than 10% gain in spectral efficiency in case of 2 hops. It is expected that gain in the spectral efficiency is increase as number of hops increases as can be seen from the figure 2.

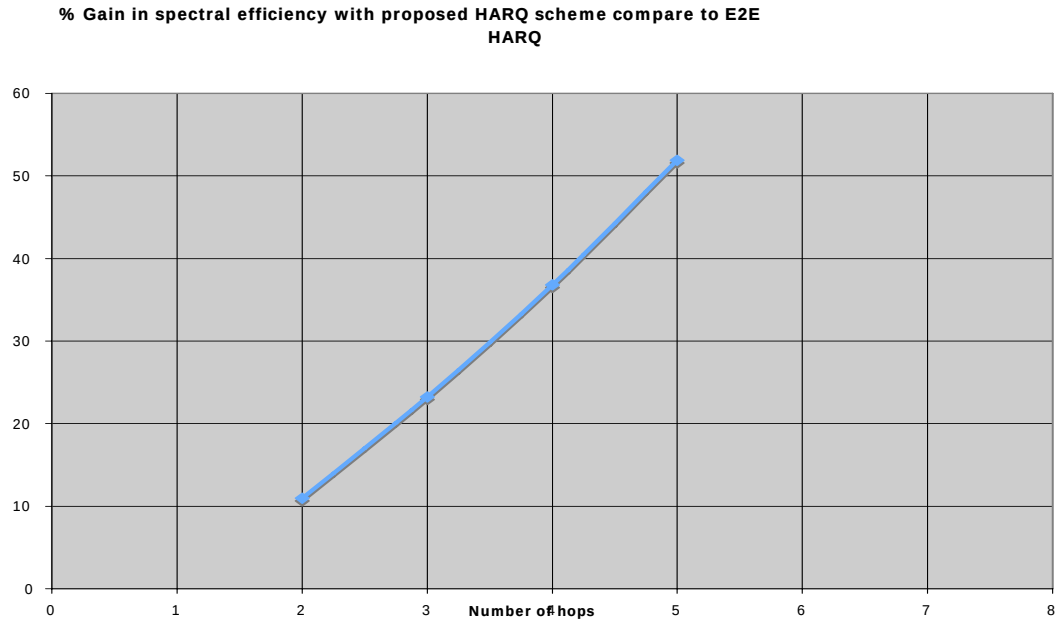

Figure 2: Gain in spectral efficiency (E-HARQ Vs E2E HARQ) QLength at RS = 4 Packets

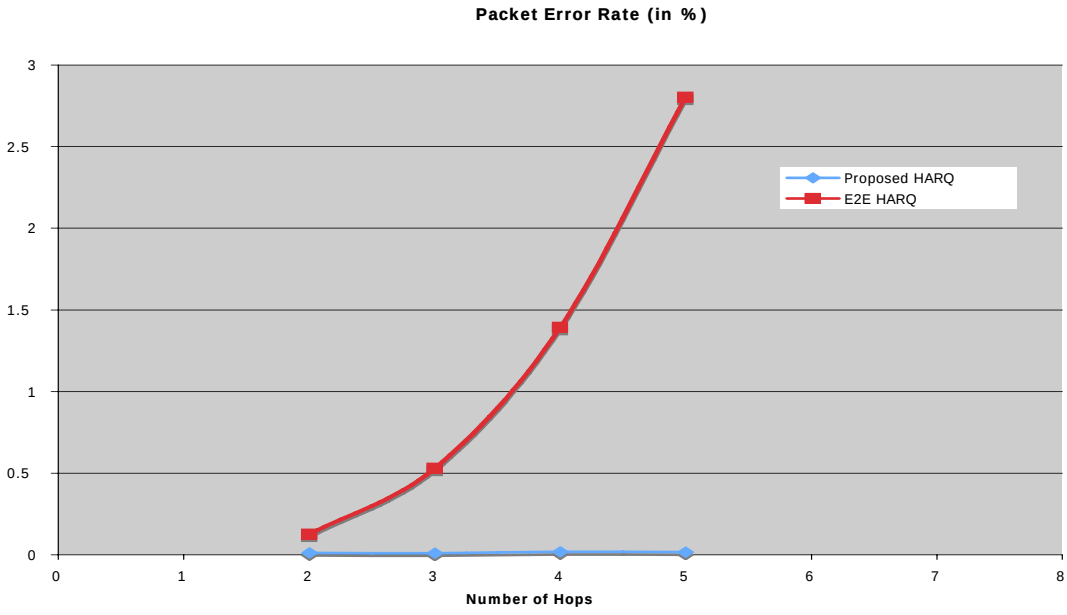

Figure 3: Packet Error Rate (After Max Retransmission for HARQ) for Proposed HARQ and E2E HARQ. (Qlength at RS is 4 packets)

Figure 3 describes the Packet Error Rate (PER) after maximum number of retransmission for HARQ is exhausted. It can be seen from the figure 3 that PER is increase as number of hops are increase for end-to-end HARQ while the PER for proposed scheme remains the same. Also PER for proposed HARQ scheme is significantly lower than end-to-end HARQ for 2 hops.

Figure 4 analyzes the requirement of queue length at the RS. It can be seen that increasing the queue length beyond threshold does not increase the performance. Also the requirement of queue length at the RS is not significant (3 packets)

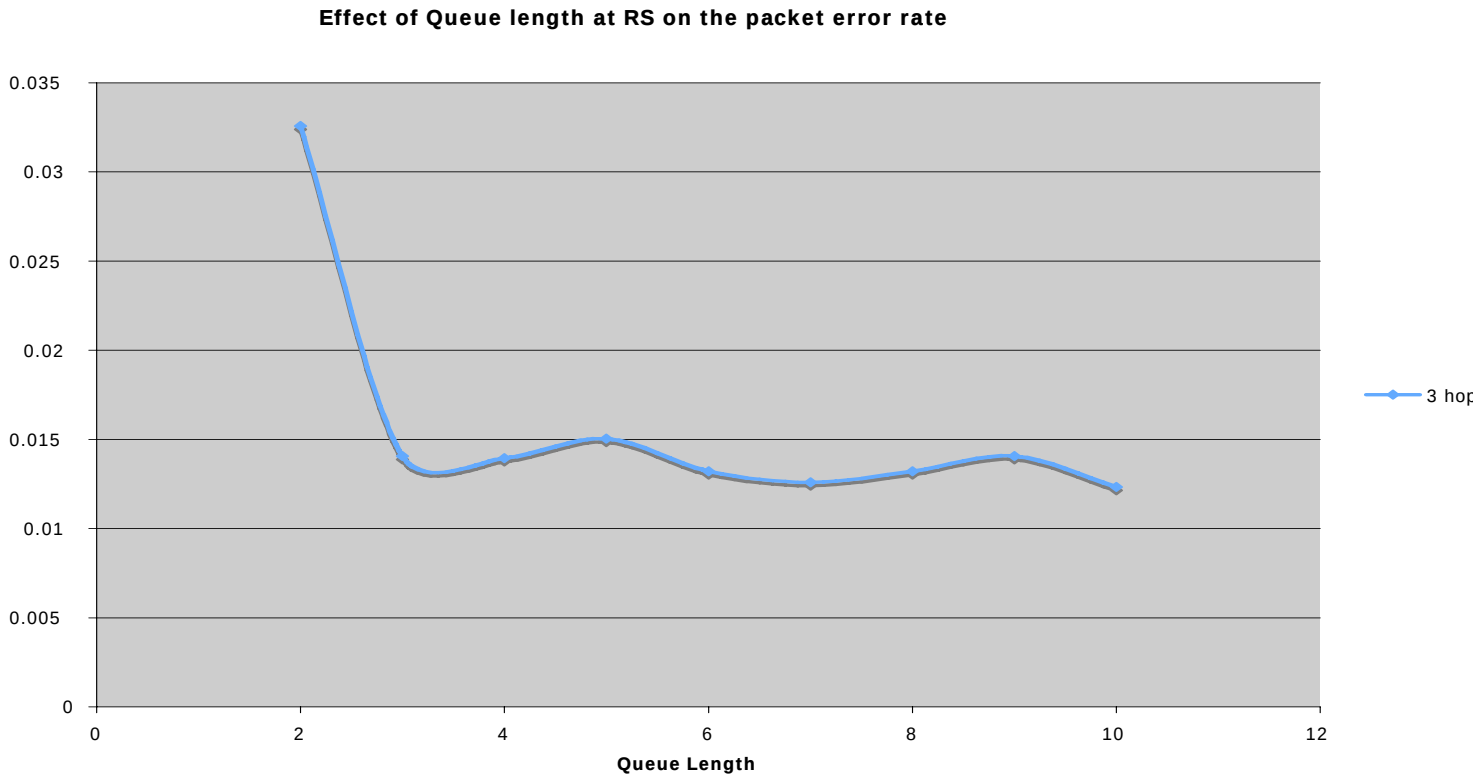

Figure 4: Effiect of Queue length on the Packet Error Rate for Proposed HARQ (for E2E HARQ, Qlength is not required. For E2E HARQ: PER is : 0.53%)

Summary

This contribution provides a mechanism for the working of HARQ in centralized scheduling. The proposal is bandwidth efficient, and works on top of the existing HARQ mechanism. It introduces error reporting for indicating the RS, where the HARQ transmission has failed; and the HARQ packet that has failed. It doesn't modify access link. The related changes to the specification are also proposed.

Specification changes

Insert new sub-clause 6.3.17.5

6.3.17.5 Relay support for HARQ in centralized scheduling

MMR-BS schedules a HARQ packet on all the links between MMR-BS and MS. Any transmission failure on a relay link is indicated to MMR-BS in a HARQ RS report, so the MMR-BS can schedule the retransmission only for the links that didn't transmit packet in the last attempt. The mechanism is different for UL and DL, and it is described below.

Insert new sub-clause 6.3.17.5.1

6.3.17.5.1 DL HARQ transmission

When MMR-BS sends a first HARQ attempt, it allocates bandwidth over all the links from the MMR-BS to the MS. Each RS on the relay path receives the downlink HARQ packet, and decodes it. If the decoding succeeds, it sends an ACK back to the previous RS/MMR-BS, and forwards the HARQ packet to the next hop. The previous RS clears the HARQ packet from its buffer after receiving the ACK. If the decoding fails, the RS sends a NAK back to the previous RS/MMR-BS. If the previous station is RS, then it is the last RS that has received the HARQ packet successfully. The last RS sends HARQ RS Report Extended subheader to the MMR-BS indicating the HARQ packet and itself. The MMR-BS sends DL-MAP accordingly, allowing retransmission from the last RS onwards, thus, retransmitting only on the links that didn't relay the HARQ packet.

The MS/SS behavior is unchanged. In case of error on any link, the MS/SS receives packet with error in the allocated burst, and sends a NAK. In case of no error, the MS sends an ACK.

Insert new sub-clause 6.3.17.5.1.1

6.3.17.5.1.1 HARQ next transmission control

For DL HARQ, the MMR-BS after receiving ACK from the next RS, could schedule next HARQ packet. When there are failures on a subsequent link, while the first link is always good. The MMR-BS could flood the relays with the HARQ packet. Therefore, RS that has successfully received the HARQ packet, but has not successfully transmitted to the next hop should be able to buffer HARQ packets, waiting for the next retransmission grant from the MMR-BS. In case the RS reaches its buffer capacity, it should send next transmission stop flag back to the MMR-BS in HARQ RS Report extended subheader.

Insert new sub-clause 6.3.17.5.2

6.3.17.5.2 UL HARQ transmission

When MMR-BS sends a HARQ attempt, it allocates bandwidth over all the links from the MMR-BS to the MS. Each RS on the relay path receives the uplink HARQ packet, and decodes it. If the decoding succeeds, it sends an ACK to the previous RS/MS and forwards the HARQ packet to the next hop. The previous RS/MS clears the HARQ packet from its buffer after receiving the ACK. If the decoding fails, the RS sends a NAK back to the previous station. If the previous station is a RS, then it is the last RS that has received the HARQ packet successfully. The last RS sends HARQ RS Report Extended subheader to the MMR-BS indicating the HARQ packet and itself. The subheader is sent in the same allocation allocated for the HARQ packet. The MMR-BS sends UL-MAP accordingly, allowing retransmission from the last RS onwards, thus, retransmitting only on the links that didn't relay the HARQ packet.

The MS behavior is unchanged with the introduction of RS. The MS does not send HARQ RS Report Extended subheader.

The ACK/NAK is sent by HARQ ACK Bitmap IE. Each RS generates HARQ ACK bitmap IE for its received HARQ packets. The UL burst positions could be altered by RS on a hop, but each receiving RS/MMR-BS keeps its mapping, and generates its HARQ ACK bitmap accordingly. The receiver of the bitmap clears the buffer corresponding to the ACK bits in the bitmap, and saves the buffer corresponding to the NAK bits.

Insert new sub-clause 6.3.17.5.3

6.3.17.5.3 Resource Request for HARQ RS Report

The HARQ RS Report is sent by a RS using any available bandwidth grant from the MMR-BS at the moment. It is possible that the RS may not have any bandwidth grant for sending the report. In this case, a CDMA ranging code method is used for requesting bandwidth grant from the MMR-BS.

The MMR-BS allocates a specific RS CDMA ranging code to a RS during initial ranging by sending RS_CDMA_Codes TLV in RNG-RSP. The code is allocated for requesting UL resource for sending HARQ RS Report Extended subheader. When RS needs to send HARQ RS Report, it sends the allocated CDMA ranging code toward the MMR-BS. The MMR-BS recognizes the RS with the help of the assigned RS code. It assigns

uplink allocation for sending HARQ RS Report Extended subheader using CDMA Allocation IE for all the links up to the RS.

Modify Table 13c in sub-clause 6.3.2.2.7

ES type	Name	ES body size	Description
5	HARQ RS Report extended subheader	TBD (= size of RSID) Need to give size	See section 6.3.2.2.7.9
~~5~~6-127	Reserved	-	-

Insert new sub-clause 6.3.2.2.7.9

6.3.2.2.7.9 UL HARQ RS Report extended subheader

Specify the last RS that has received the UL HARQ attempt successfully. The subheader is sent with a MAC header containing basic CID for the RS. The RS basic CID helps MMR-BS in identifying the RS. The format of HARQ RS Report extended subheader is as described in table T1.

Table T1 – HARQ RS Report Extended Subheader

Name	**Size**	**Description**
CID	16 bits	CID of the MS connection
AI_SN	1 bit	HARQ ID Seq. No
SPID/Reserved	2 bits	Subpacket ID when IR is defined by the FEC mode, otherwise reserved (encoded 0b00)
ACID	4 bits	The ID of the HARQ channel that carries the UL HARQ attempt.
Next Transmission Flag Included	1 bit	= 1, Next Transmission Flag is applicable = 0, Next Transmission Flag is don't care
Next Transmission Flag	1 bit	= 1, request to MMR-BS for stopping next HARQ packet

		transmission = 0, request to MMR-BS for resuming next HARQ packet transmission
UL/DL-HARQ	1 bit	= 1, indicates the report is related to UL HARQ = 0, indicates the report is related to DL HARQ
Reserved	6 bits	

The following changes are on top of the changes proposed in [1].

Insert new subclause 11.19.1:

11.19 RS_RNG-RSP management message encodings
The encodings described in this subclause are specific to the RS_RNG-RSP message.

Insert new subclause 11.19.1:

11.19.1 RS CDMA Codes TLV

Name	Type (1 byte)	Length	Value
RS CDMA Code	-	3	The TLV carries 1 byte ranging code in the following order - HARQ Error Report

References

[1] Resource Request for Bandwidth, C80216j-06_189.doc; Yousuf Saifullah, Shashikant Maheshwari, and Haihong Zheng; Nokia