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| Re: | This is in response to the call for technical comments and contributions regarding IEEE Project 802.16j (80216j-07_007r2.pdf) |
| Abstract | This document proposes a method for shortening the end-to-end HARQ data transfer latency along the relay path in a relay system. |
| Purpose | Add proposed spec changes in P802.16j Baseline Document (IEEE 802.16j-06/026r2). |
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| | <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>. |

# Pipeline HARQ in Multi-hop Relay System

## Introduction

In multi-hop relay system, one or more relay stations may involve in the traffic relaying along the relay path from MR-BS to MS or vice versa. Considering the procedure of handling retransmission of HARQ failure attempt in multi-hop scenario, the logical HARQ channel between MR-BS and MS could be performed in either the end-to-end or the hop-by-hop manner depending on which station generating the ACK indication. Generally, in the fashion of end-to-end HARQ, the ACK messages are only generated from either the MR-BS or the MS according to the direction of data flow. On the other hand, the MR-BS, MS and RS are able to generate ACK indications in the fashion of hop-by-hop HARQ.

In relay system, the MAP generation and bandwidth allocation could be done in centralized or distributed manner. In centralized scheduling system, the MR-BS generates MAP and schedules bandwidth for all the links. In distributed scheduling system, the MR-BS and RS individually generates MAP and schedules bandwidth for the adjacent link. For end-to-end HARQ channel in centralized scheduling system, the bandwidth required for relaying the HARQ data packet could be pre-allocated for all the links along the relay path between MR-BS and MS. If any HARQ packet transmission failure occurs on a link, then the failure shall be reported to the MR-BS in order to request bandwidth for retransmission on the effected links. For hop-by-hop HARQ channel in centralized scheduling system, the bandwidth required for relaying the HARQ data packet could be sequentially allocated for the links along the relay path, one by one. From above descriptions, if the HARQ packet is received incorrectly at an RS, it will not forward the incorrectly received packet to next hop RS. Therefore, a longer HARQ packet transfer delay between MR-BS and MS is inevitable in a multi-hop relay system no matter either the end-to-end or hop-by-hop approach is adopted.

This contribution is mainly aimed at efficient HARQ transmissions in multi-hop relay system with centralized control and scheduling approach. Moreover, it suggests the mechanism that will work on the chase combining HARQ (type I) and incremental-redundancy HARQ (type II).

## Proposed Pipeline HARQ

This contribution introduces a pipeline HARQ method to minimize the end-to-end HARQ packet transfer latency. The feature of short end-to-end transfer latency is essential for providing good quality of real-time services, such as VoIP, video streaming, interactive gaming, and so on.

HARQ renders performance improvement achieved by combining previously erroneously decoded packet and retransmitted packet. From the system-wise viewpoint, all previously erroneously decoded packets at an intermediate station are still carrying useful information for its successors more or less. Thus, the RS supporting the pipeline HARQ could relay previously erroneously decoded packets, which were sent from its predecessor, to its successor just as the success case does. It is trivial for incremental redundancy HARQ method because those encoded HARQ subpackets may carry different part of parity check block by applying the puncture patterns. That is, the coded block may not the same for each retransmission. Contrarily, chase combining method encodes HARQ packet by generating one version encoded packet with 16-bit CRC. It uses a simultaneous error correction and detection code, and the whole codeword is transmitted and/or retransmitted. To achieve the diversity gain, RS supporting chase comabining is required to adopt some smart algorithms to retrieve correct data from all previously erroneously decoded packets in order to minimize the number of retransmissions. This contribution only focuses on the efficient procedure of handling the HARQ data relaying and retransmissions. The design of smart decoding algorithm is out of the scope of this contribution.

## RS supporting pipeline HARQ

Each RS on the relaying path from MR-BS to MS or vice versa should:

- **buffer** all received HARQ packets until it receives the explicit ACK indication to it
- **forward** the first received packet from its predecessor to its successor regardless of the correctness of the packet
- **resend** one of previously erroneously decoded packets to the successor until it receives the explicit ACK indication to it
- **report** the ACK (or NACK) to the MR-BS (centralized scheduling) or RS (distributed scheduling) according to the status of decoding the received packet combining with previous ones
- **relay** the ACK/NACK to the next station
- **stop** forwarding packets and **release** buffer if it receives the explicit ACK indication to it

In the system adopting the pipeline HARQ technique, the HARQ packet size and the seed of randomizer must be the same on every link along the relay path. Each time RS receives an ACK sent from successor, the RS shall forward received ACK to the predecessor, finally to the destination such as MR-BS or MS. On the other hand, it is optional for RS to forward an NACK indication. If the NACK is not forwarded by RS, the bandwidth that is granted for retransmissions of all downlinks behind correspondent RS will be automatically generated by the event of ACK/NACK timeout.

## Proposed DL pipeline HARQ in centralized scheduling

In DL HARQ scenario, the data packets are sent from MR-BS to MS via a number of intermediate RSs. As shown in Figure 1, HARQ data packet will be sent from MR-BS to the RS1, and is forwarded to RS 2 and finally to the MS. For the purpose of efficiency, the bandwidth for relaying the HARQ packet and status report on all the links along the relay path could be prescheduled by MR-BS. If the HARQ packet sent from MR-BS can not be successfully decoded at RS1, RS1 shall report the NACK signal back to MR-BS to indicate the retransmission request. Considering the feature of HARQ and prescheduled bandwidth, the data received by RS1 could be relayed to RS2 regardless of the correctness of that packet. Of course, relaying a partially corrupted data packet will result in negative report from RS2 to MR-BS and from MS to MR-BS as well. NACK indications generated from RS may not be forwarded by upstream RS if upstream RS needs to use the Fast Feedback UL subchannel to report the channel quality instead of NACK indication. If NACK is not forwarded by RS, the event of ACK/NACK timeout will trigger MR-BS to automatically grant bandwidth for retransmissions on effected links.

As a response to a successful reception of the data at the MS/RS, MS/RS generates ACK indication to notify MR-BS the stopping of HARQ retransmissions from its predecessor to it. All ACK indications are forwarded and finally to the MR-BS. It is desired to have a mechanism for MR-BS to tell which station sending the ACK or NACK indication and then determine which links that required the bandwidth for HARQ retransmissions. Related method can be found in [1].

In Figure 1, notation ‘Data’ indicates the data is successfully transmitted, notation ‘Data*’ indicates the data is corrupted by noise during transmission, and notation ‘Data(*)’ indicates the data is partially corrupted but is sufficient for RS with some smart algorithm to successfully decode data. It is optional for RS to issue NACK indication.

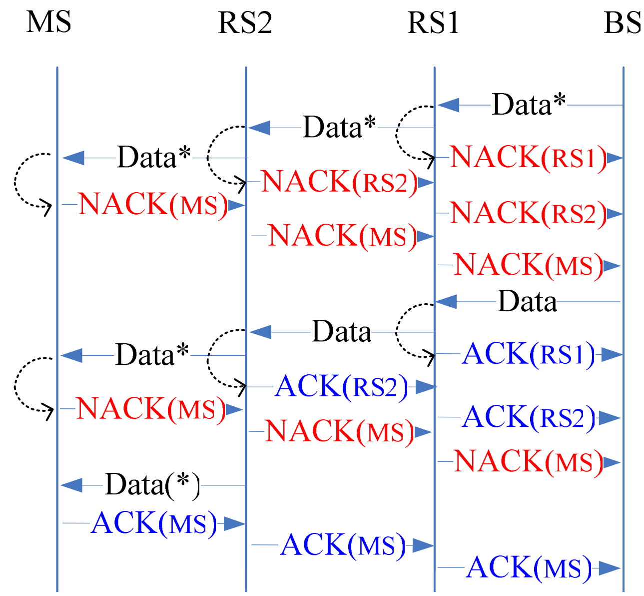


Figure 1. Message Flow for 3-hop DL pipeline HARQ.

## Proposed UL pipeline HARQ in centralized scheduling

The data flow of uplink HARQ is in the opposite direction as that illustrated in Figure. 1. System requires to setup two contra-directional ACK channels for an uplink pipeline HARQ channel : the UL ACK channel and the DL ACK channel. The ACK/NACK transmitted on UL ACK channel and DL ACK channel are denoted as UL ACK/NACK and DL ACK/NACK respectively. The DL ACK/NACK is carried in HARQ ACK bitmap IE as in current 16e spec, and all HARQ ACK bitmap IEs are generated by MR-BS with centralized MAP allocations. The followings list their requirements and purposes :

- DL ACK to RS/MS is mandatory and is used to stop retransmission at RS or MS
- DL NACK to MS is mandatory and is used to indicate the requirement of retransmission
- DL NACK to RS is optional and is used to indicate the requirement of retransmission
- UL ACK from RS is mandatory and is used to trigger MR-BS to generate DL ACK (in HARQ ACK bitmap IE) to the successor of the RS which sent the UL ACK indication
- UL NACK from RS is optional and is used to notify MR-BS it needs receive packet from its successor again
- UL ACK from MS is meaningless
- UL NACK from MS is meaningless

Figure 2 illustrates the uplink pipeline HARQ with necessary UL ACK and DL ACK/NACK indications. Note that UL NACK sent from RS is optional. In Figure 2, as RS2 receives a corrupted packet from MS, it keeps forwarding the packet to RS1 and finally to the MR-BS. The UL NACK(RS1) and UL NACK(RS2) may be generated from RS1 and RS2 for the purpose of notifying MR-BS the failed receptions at RS1 and RS2 respectively. If UL NACK indications are not sent out from RS, the related ACK/NACK timer in MR-BS will expire. Such event represents the reception of NACK from RS. If MR-BS can not successfully decode the packet too, it replies the DL NACK(MS) indication (via HARQ ACK Bitmap IE) to MS to indicate the retransmission request. For the first retransmission, data is assumed to be successful at the first link from MS to RS2, and to be failure at the other two links. As a result, RS2 issues the UL ACK(RS2) to trigger MR-BS to generate the DL ACK(MS) to MS which is the successor of RS2 to stop retransmission at MS. Moreover, retransmissions on effected links are repeated again. As the packet retransmissions from RS2 to RS1 and RS1 to MR-BS are successful, UL ACK(RS1) and DL ACK(RS2) are generated as shown in Figure 2.

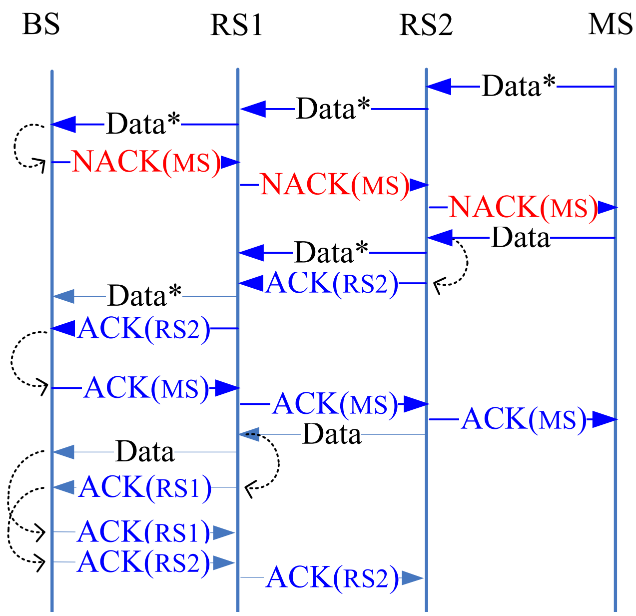


Figure 2. Message Flow for 3-hop UL pipeline HARQ.

It is optional for an RS to report explicit NACK to MR-BS to indicate the retransmission request. As the ACK/NACK timer expired, the BS treats such event as the implicit NACK reception and automatically grants bandwidth for retransmissions on related links. Similarly, it is optional for a BS to send explicit NACK to RS to indicate the retransmission request because MR-BS controls all retransmissions by using HARQ-MAP IE. According to the aforementioned descriptions, when a system adopting the pipeline HARQ technique, HARQ packet is retransmitted by station until it receives the explicit ACK indication. To minimize the influence from the corrupted ACK/NACK indications, a BS may allocate multiple uplink/downlink logical ACK channels for MS/RS along the relay link, one for each.

## Conclusion

In summary, a multi-hop relay system using pipeline HARQ technique can efficiently minimize the end-to-end latency by permitting an RS to relay previously erroneously decoded packets to its successor if the bandwidth on links along the relay path has be prescheduled.

## Proposed text changes

*Insert new sub-clause 6.3.17.5*

6.3.17.5 RS supporting Pipeline HARQ in centralized scheduling

Each RS on the relaying path from MR-BS to MS or vice versa should:

– **buffer** all received HARQ packets until it receives the explicit ACK indication to it

- **forward** the first received packet from its predecessor to its successor regardless of the correctness of the packet
- **resend** one of previously erroneously decoded packets to the successor until it receives the explicit ACK indication to it
- **report** the ACK to the MR-BS (centralized scheduling) or RS (distributed scheduling) according to the status of decoding the received packet combining with previous ones
- **relay** the ACK/NACK to the next station
- **stop** forwarding packets and **release** buffer if it receives the explicit ACK indication to it

In the system adopting the pipeline HARQ technique, the HARQ packet size and the seed of randomizer shall be the same on every link along the relay path. RS shall forward all received ACK indications to the next station, finally to the destination such as MR-BS or MS. NACK indications are only generated from MS and MR-BS. The event ACK/NACK timeout of MR-BS will force MR-BS to trigger retransmissions on effected links. The MS behavior is unchanged with the introduction of RS.

#### 6.3.17.5.1 DL Pipeline HARQ in centralized scheduling

MR-BS schedules the bandwidth for relaying a HARQ packet on all the links along the relay path from MR-BS to MS. It also schedules the bandwidth for relaying upward ACK/NACK indications on UL ACK channels from RSs and MS.

Upon RS receiving the HARQ packet, it first decodes the received packet and then forwards it to its successor according to HARQ MAP IE regardless of the correctness of the decoded packet and replies the ACK indication to MR-BS if the decoded packet is correct. If MS failed to decode HARQ-burst correctly, it replies NACK to MR-BS as in current 16e specification. As a response to a successful reception of the data, MS or RS shall generate ACK indication to notify MR-BS the stopping of HARQ retransmissions from its predecessor to it. All ACK indications and NACK indications from MS are forwarded by upstream RS(s) and finally to the MR-BS. The event of ACK timeout for an MS/RS in MR-BS represents the reception of implicit NACK indication from related MS/RS. The ACK/NACK timeout is defined in the parameter HARQ ACK Delay for UL/DL Burst broadcast by DCD message. MR-BS determines the links of DL transmission failure and then schedules the retransmission only for the effected links that didn't transmit packet successfully in the last attempt.

#### 6.3.17.5.2 UL Pipeline HARQ in centralized scheduling

MR-BS schedules the bandwidth for relaying a HARQ packet on all the links along the relay path from MS to MR-BS. It also schedules the bandwidth for relaying upward ACK indications on UL ACK channels from RSs to MR-BS and the bandwidth for relaying downward ACK/NACK indications to RSs and MS.

Upon RS receiving the HARQ packet, it first decodes the received packet and then forwards it to its successor according to HARQ MAP IE regardless of the correctness of the decoded packet and replies the ACK indication to MR-BS if the decoded packet is incorrect. If MR-BS failed to decode HARQ-burst correctly and there is no ACK indication from RS, it replies NACK to MS via HARQ ACK bitmap IE as in current 16e specification.

As a response to a successful reception of the data, RS shall generate upward ACK indication to notify MR-BS to stop HARQ retransmissions from its predecessor to it. Such upward ACK indication arrives at MR-BS will trigger MR-BS to send another downward ACK indication to the RS/MS which is the successor of the RS sending the upward ACK indication. For example, the ACK indication from the access RS will result in an ACK indication to MS via HARQ ACK bitmap IE from MR-BS.

All ACK indications and NACK indication to MS are forwarded by RS(s). The event of ACK timeout in RS and MR-BS represents the reception of implicit NACK indication. MR-BS determines the links of UL transmission failure and then schedules the retransmission only for the effected links that didn’t transmit packet successfully in the last attempt.