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Title	Pipeline HARQ for multi-relay system
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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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Pipeline HARQ with Relay

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 latency 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 retransmissions 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 in multi-hop relay system with centralized scheduling to minimize the unnecessary retransmissions on links along the relay path. The feature of minimal unnecessary retransmissions on links on relay path is essential for providing high system throughput.

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** correctly decoded packets from its predecessor to its successor
- **resend** correctly decoded packets to the successor if it is scheduled to retransmit
- **report** the ACK/NACK to the MR-BS according to the status of decoding the received packet
- **relay** the ACK/NACK to the next station
- **stop** forwarding packets and **release** buffer if it receives the explicit ACK indication to it

In both cases of UL HARQ channel and DL HARQ channel, RS always reports MR-BS the status of decoding the received packet. To provide fault tolerance on ACK/NACK indications, each RS sends separate ACK/NACK to MR-BS. Each time RS receives an ACK/NACK sent from the successor, the RS shall forward the received ACK/NACK to the predecessor, finally to the destination such as MR-BS or MS. Upon MR-BS

receiving the NACK indication from an RS or MS, it schedules the bandwidth for retransmissions on all effected links related to the RS or MS.

Proposed DL pipeline HARQ in centralized scheduling

In DL HARQ scenario, the data packets may be sent from MR-BS to MS via RS. As shown in Figure 1, HARQ data packet will be sent from MR-BS to RS1, and is forwarded to RS2 and finally to MS. In Figure 1, notation 'Data' indicates the HARQ packet is successfully transmitted, notation 'Data*' indicates the HARQ packet is disturbed by noise during transmission, and notation 'Dummy' indicates the allocated HARQ sub-burst is replaced by dummy information. For the efficiency purpose, the bandwidth for relaying the HARQ packet and status report on all the links along relay path could be prescheduled by MR-BS. If RS1 failed to decode HARQ packet correctly, RS1 does not relay the erroneous packet to the next hop and it reports NACK signal back to MR-BS to indicate the retransmission request. In this case, RS sends dummy information with padding bits on the allocated HARQ sub-burst to the next hop such that MS or further downstream RS also fails to decode the HARQ burst correctly and replies separate NACK back to MR-BS consequently.

As a response to a successful reception of the data at the MS or RS, MS or RS shall generate separate ACK indication to notify MR-BS the stopping of HARQ retransmissions from its predecessor to it.

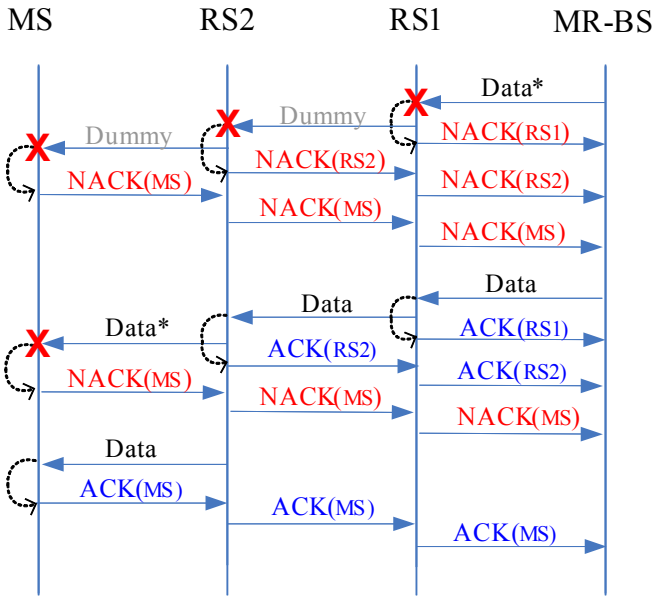

Figure 1. Message flow for 3-hop DL pipeline HARQ.

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 HARQ ACK bitmap IEs could be generated by access RS or MR-BS. The followings list their requirements and purposes :

- DL ACK destining to MS shall be generated by access RS. It is used to stop retransmission at MS

- DL NACK destining to MS shall be generated by access RS. It is used to indicate the requirement of retransmission
- DL ACK destining to RS shall be generated by MR-BS. It is used to stop retransmission at RS
- DL NACK destining to RS may be generated by MR-BS. It is used to indicate the requirement of retransmission
- UL ACK shall be generated by RS and forwarded to MR-BS. It is used to trigger MR-BS to generate DL ACK to the successor of the intermediate RS sending the UL ACK
- UL NACK shall be generated by RS and forwarded to MR-BS. It is used to notify MR-BS that it needs receive packet from its successor again

Figure 2 illustrates the uplink pipeline HARQ with necessary UL ACK/NACK and DL ACK/NACK indications. Notations used in Figure 2 are the same to that shown in Figure 1. In Figure 2, as access RS RS2 failed to decode HARQ packet from MS correctly, it sending the dummy information with padding bits to the next hop, RS1, and finally to the MR-BS. RS2 replies the DL NACK(MS) such that MS can receive ACK/NACK before ACK timeout. The UL NACK(RS1) and UL NACK(RS2) shall be separately sent from RS1 and RS2 for the purpose of notifying MR-BS the failed receptions at RS1 and RS2 respectively. In this case, MR-BS can not correctly decode the packet and there is no ACK indication sent from RS. Then, MR-BS schedules retransmission on all links from MS to MR-BS. For the first retransmission, data is assumed to be successful at the access link from MS to RS2 and at the relay link from RS2 to RS1, and to be failure at the last link. As a result, RS2 generates the DL ACK(MS) and replies it to MS. Moreover, RS2 and RS1 respectively send UL ACK(RS2) and UL ACK(RS1) to MR-BS and the latter will trigger MR-BS to generate the DL ACK(RS2) which is used to release the buffer at RS2. After then, retransmission on effected link from RS1 to MR-BS is repeated again. As the packet retransmission from RS1 to MR-BS is successful, DL ACK(RS1) is generated accordingly as shown in Figure 2.

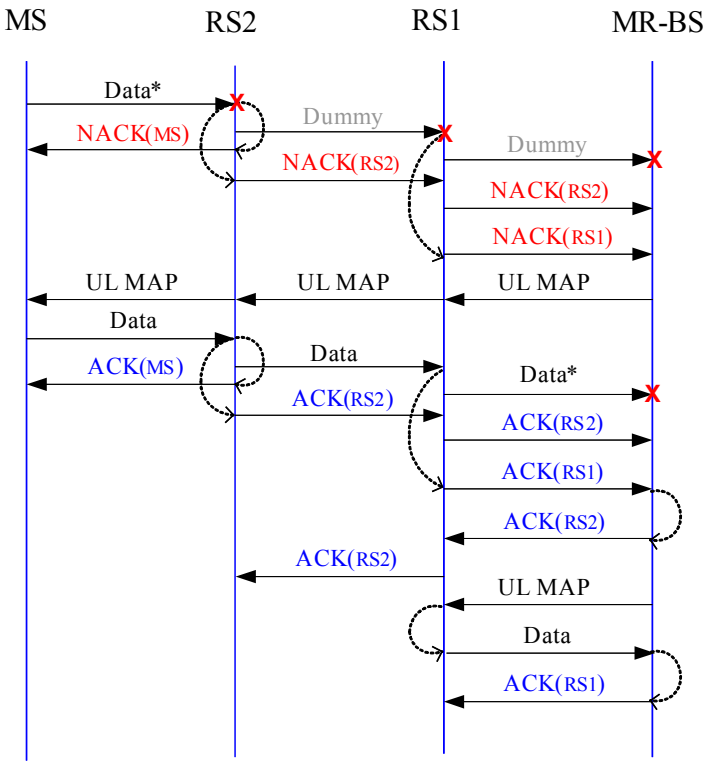

Figure 2. Message flow for 3-hop UL pipeline HARQ.

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 from a station until it receives the explicit ACK indication. To minimize the unnecessary retransmissions caused from any loss ACK/NACK indication along the way to MR-BS, MR-BS should allocate one uplink and one downlink ACK channel for MS and every RS on the path.

Conclusion

In summary, a multi-hop relay system using pipeline HARQ technique can efficiently determined the effected links required for retransmissions and reduce the unnecessary retransmissions caused from the potential loss of ACK/NACK indication along the relay path to MR-BS.

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 correctly decoded packets from its predecessor to its successor
- resend correctly decoded packets to the successor if it is scheduled to retransmit
- report the ACK/NACK to the MR-BS according to the status of decoding the received packet
- relay the ACK/NACK to the next station
- stop forwarding packets and release buffer if it receives the explicit ACK indication to it

Per UL HARQ channel or DL HARQ channel, MR-BS should allocate one ACK channel for every RS on the path. It requires each RS on the path to send separate ACK/NAK signal back to the MR-BS. RS shall forward every received ACK/NACK to the next station, finally to the destination such as MR-BS or MS. 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 allocates the bandwidth for relaying separately upward ACK/NACK on UL ACK channels from MS and RSs on the path.

If RS or MS failed to decode the received HARQ-burst correctly, it replies a NACK to MR-BS as in current 16e specification. In this case, RS sends dummy information with padding bits on the pre-allocated HARQ sub-burst to the next hop such that MS or further downstream RS also fails to decode the HARQ burst correctly and then replies separate NACK back to MR-BS consequently.

As a response to a successful reception of the data, MS or RS shall forward the HARQ packet to the next hop and reply ACK to notify MR-BS the stopping of HARQ retransmission from its predecessor to it. Every ACK/NACK sent from MS or RS is forwarded by upstream RS(s) and finally to the MR-BS.

The event of ACK/NACK timeout for an MS or RS at MR-BS represents the reception of implicit NACK from

related MS or RS. The ACK/NACK timeout is defined in the parameter HARQ ACK Delay for DL Burst broadcast by UCD message.

MR-BS determines the links of DL transmission failure by referring to all received ACK/NACK signals and then schedules the retransmission only for the effected link(s) 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 separately upward ACK/NACK on UL ACK channel from RS to MR-BS and the bandwidth for relaying separately downward ACK/NACK from MR-BS to RS and from access RS to MS.

An RS shall send NACK to MR-BS if the decoded HARQ-burst is incorrect. In this case, RS sends dummy information with padding bits on the pre-allocated HARQ sub-burst to the next hop such that further upstream RS also fails to decode the HARQ burst correctly and sends separate NACK to MR-BS consequently. If access RS failed to decode HARQ-burst correctly, it shall reply 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 forward the HARQ packet to the next hop and generate ACK to notify MR-BS to stop HARQ retransmissions from its next downstream station. Such ACK, which is sent from intermediate RS, arriving MR-BS will trigger MR-BS to send an ACK, which is carried in HARQ ACK bitmap IE, to the RS which is the next downstream station of the RS sending the ACK signal. If access RS decodes the HARQ-burst correctly, it shall reply ACK to MS via HARQ ACK bitmap IE as in current 16e specification.

Every ACK/NACK on UL ACK channel is forwarded by upstream RS(s) and finally to the MR-BS. Every ACK/NACK carried in HARQ ACK bitmap IE is forwarded by RS(s) and finally to the destination RS or MS.

The ACK/NACK timeout event for an MS or RS at MR-BS represents the reception of implicit NACK from related MS or RS. The ACK/NACK timeout is defined in the parameter HARQ ACK Delay for UL Burst broadcast by DCD message.

MR-BS determines the links of DL transmission failure by referring to all received ACK/NACK signals and then schedules the retransmission only for the effected links that didn't transmit packet successfully in the last attempt.