HARQ in Multi-hop Relay System

IEEE 802.16 Presentation Submission Template (Rev. 8.3)

Document Number:

IEEE S802.16j-07/185r3

Date Submitted: 2007-04-06

Source:

Kanchei (Ken) Loa, Youn-Tai Lee, Shiann-Tsong Sheu, Yi-Hsueh Tsai, Hua-Chiang Yin, Yung-Ting Lee, Heng-Iang Hsu, Frank C.D. Tsai,	Voice:	886-2-2739-9616
Institute for Information Industry	Fax:	886-2-2378-2328
8F., No. 218, Sec. 2, Dunhua S. Rd., Taipei City, Taiwan.	E-mail:	loa@iii.org.tw
Hang Zhang, Mo-Han Fong, G.Q. Wang ,Peiying Zhu,	Voice:	+1 613 7631315
Wen Tong, David Steer, Gamini Senarath, Derek Yu, Mark Naden	E-mail:	WenTong@nortel.com
Nortel		
3500 Carling Avenue		
Ottawa, Ontario K2H 8E9		

Venue:

IEEE 802.16 Session #48, Orlando, USA

Base Document:

IEEE C802.16j-06/026r2 and URL <http://ieee802.org/16/… C80216j-06_026r2.pdf>

Purpose:

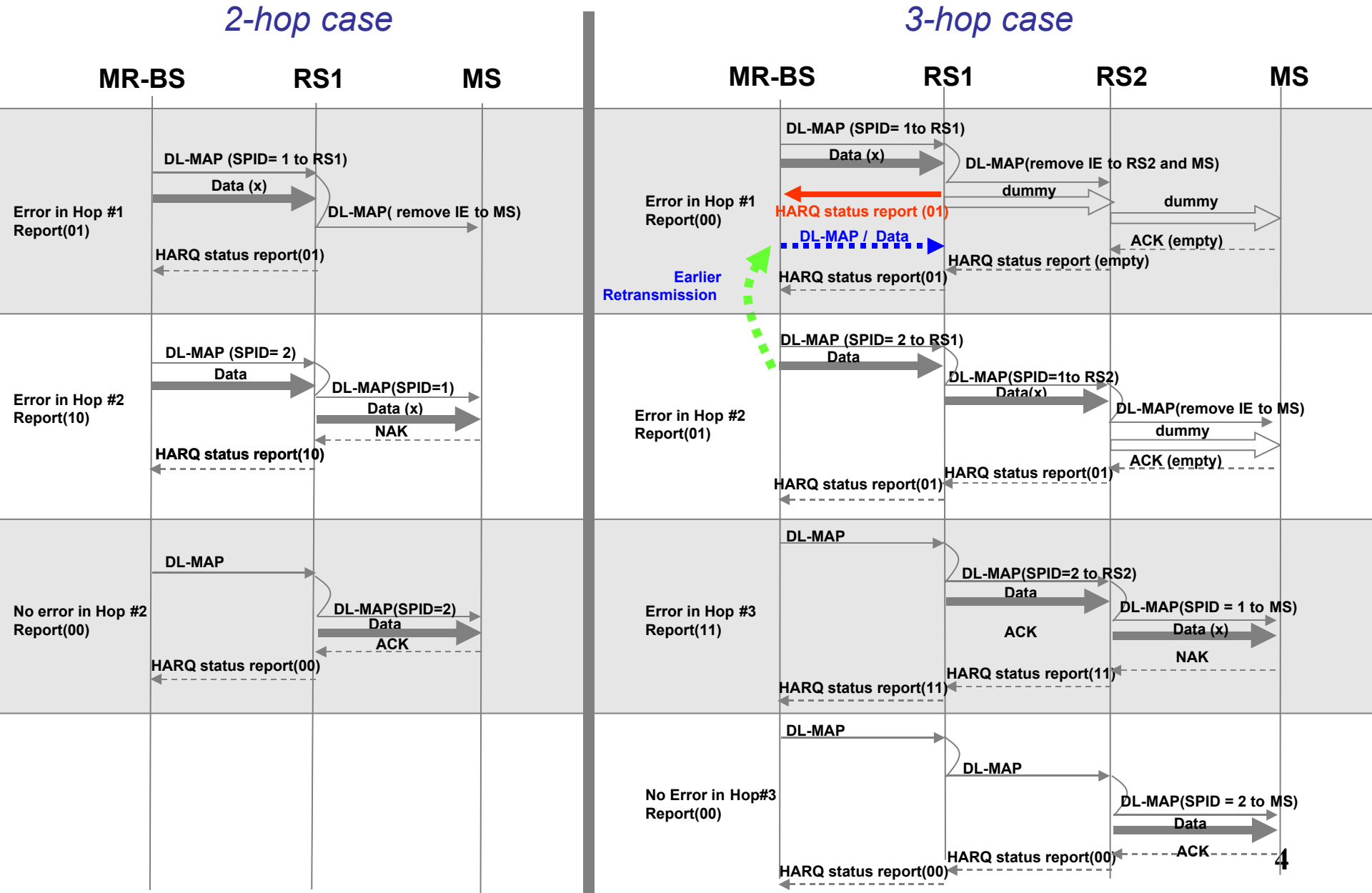
Propose the text regarding pipeline HARQ in a multi-hop relay system.

Introduction

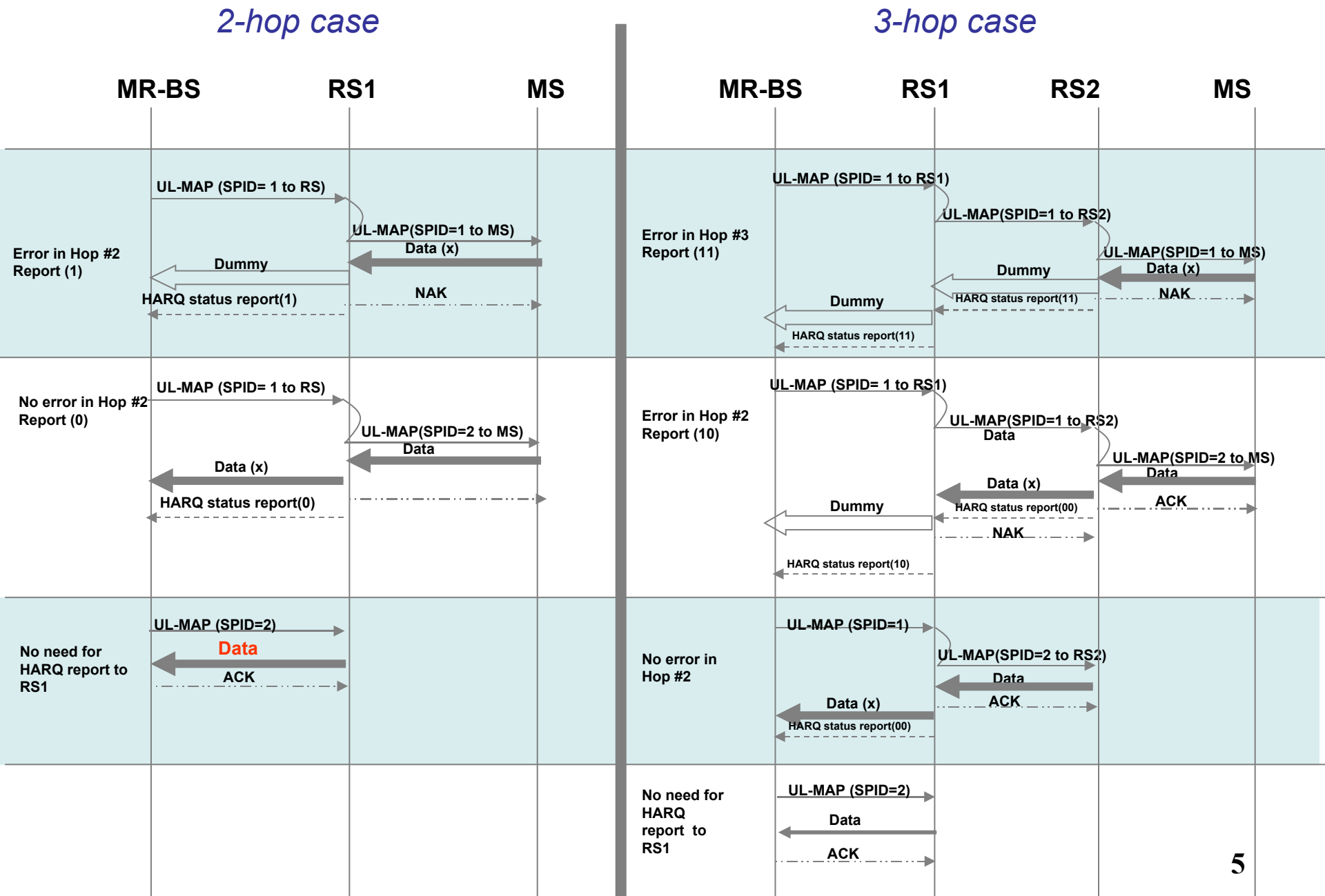
- This contribution proposes several schemes for handling HARQ in a MR system under centralized scheduling, which include
  - Centralized Scheduling Based HARQ and Report Channel
  - Multicast HARQ for transparent RS
  - Dummy HARQ pattern
  - Dedicated ACK channel for each RS
  - Recovery ACK channel

Part-1: Centralized Scheduling Based HARQ and Report Channel

Flow Diagram for UL HARQ with Centralized Scheduling



Flow Diagram for DL HARQ with Centralized Scheduling



HARQ Report Channel for Each HARQ Channel

- For saving the radio resource, MR-BS may allocate a ACK report channel shared by the RSs along a relay path
  - No any ACK/NACK channel needs to be assigned any more to RSs
  - The physical channel design for 6-bit CQICH can be reused for a new physical channel called as 6-bit HARQ report channel
    - A 6-bit HARQ report channel can be used for
      - 3 HARQ channels for a less than 4-hop case
      - 2 HARQ channels for a up to 7-hop case
  - A HARQ status report created by a RS only when the RS fails in decoding the packet
    - report the failure hop number
  - For the last hop status report, a HARQ status report created by an access RS if the RS forwarded a packet to MS and receives a MS
    - ACK: report success code (all zero)
    - NACK: report the hop number

Compact HARQ Report Channel - DL

- **Synchronized HARQ ACK scheme**
  - For a N-hop case, for each HARQCH
    - For DL data forwarding, the resources for N hops are assigned at the same time
      - including N MAP_IEs → N-1 for R-link and one for access link
    - For DL HARQ status report, the resources are assigned at the same time
- **A DL HARQ status report for one HARQ channel used to report the HARQ forwarding status**
  - **indicates the failure hop**
- **The number of bits depends on the number of hop**
  - For Number of hop < 4; → N_rep = 2
    - Encoding: 01 = first hop in error; 10 = second hop in error; 11 = third hop in error; 00 = attempt success
  - For 3 <Number of hop < 8; → N_rep = 3
    - Encoding: 001-111 denote failure in first, second,…,seventh hop; 000 denotes attempt success
- **A HARQ status report forwarding by an intermediate RS**
  - **A RS forwards HARQ status report from its subordinate RS (if any) shall simply forward without modification**
- **The station which creates MAP-IE modifies the SPID according to the HARQ status report received**

Compact HARQ Report Channel - UL

- Scheduling scheme
  - For a N-hop case, for each HARQCH
    - For UL data forwarding, the resources for N hops are assigned at the same time
      - including N MAP_IEs → N-1of them for R-link and one IE for access link
- A UL HARQ status report for one HARQ channel is used for a RS to report HARQ packet reception status
  - For each UL HARQ channel, a UL HARQ status report channel is assigned to each involved RS along with the resource for forwarding the data packet
- The number of bits required for a HARQ report depends on the number of hop
  - If N_rep = 2 supporting up to 4 hop case
    - Encoding: 01-11 to indicate the failure hop 2,3,4. 00 (all zero) indicates success
  - If N_rep = 3
    - Encoding: 001-111 to indicate failure hop 2 -8; 000 all zero) denotes success
- A HARQ status report process
  - Be created only when a RS received a UL packet
    - If the decoding is success the RS sends a ACK to the child RS (or MS) and at the same time, sends the UP HARQ report (00) upstream
    - If the decoding is not success, the RS sends a NAK to the child RS (or MS), at the same time, sends the UP HARQ report (Hop number)
  - A HARQ status report forwarding
    - A RS only needs to forward a non-all-zero report from its child (some error happens already in the path). The RS uses assigned HARQ report channel to carry it's child's report
- The station which creates MAP-IE modifies the SPID according the HARQ status report received

Part-2: Multicast Based HARQ for Transparent RS(s)

Multicast HARQ Scheme for Transparent RSs

- In a transparent relay system, an efficient method for supporting UL/DL HARQ in multi-hop relay system is proposed by involving multiple transparent RSs in the HARQ process
- With centralized control of MR-BS, bursts for transparent RSs could be easily assigned to multiple RS (multicast) with MAP IEs describing the same burst
- For each hop, MR-BS groups a number of transparent RSs, called MHARQ group which may be a subgroup of virtual group
  - Each UL/DL HARQ packet is sent to the group
  - Each RS in the group may send an ACK to MR-BS if the received data is correct. Otherwise, the RS may send a NACK to MR-BS
  - Any RS shall forward the received ACK/NACK to the next hop
  - Forwarding data should be started from an RS, which has correctly received the HARQ packet, to the MHARQ group of next hop or to the destination station directly

Solution 1: Multicast HARQ with Hop-by-hop Scheduling

- Data is scheduled/forwarded to the next hop when MR-BS receives at least one ACK from RS in MHARQ group
  - If none of ACK is received by MR-BS, MR-BS shall retransmit a HARQ packet to the MHARQ group
  - If any ACK is received by MR-BS, MR-BS shall schedule one or more RSs which sent ACK to forward data to the next hop
  - RSs should free their HARQ buffers if
    - no free command/message within timer is received, or
    - free command/message is received, or
    - new data is received (by toggled AI_SN)
- It will cause long end-to-end transfer latency

Solution 2: Multicast HARQ with End-to-end Pre-scheduling

- For each relay link, MR-BS pre-schedules one or more designated RSs of the corresponding MHARQ group to forward data in advance
  - If one designated RS failed to decode data correctly, then it shall send a NACK to MR-BS and
    - do not send data to next hop, or
    - send dummy pattern to next hop
  - If one designated RS in a hop has correctly received HARQ data, it should forward the received HARQ data to the next hop
  - If none of ACK is received by MR-BS in a MHARQ group, MR-BS shall retransmit a HARQ packet to the MHARQ group

Example 1:
DL Multicast HARQ vs. Conventional DL HARQ with Hop-by-hop Scheduling

Conventional DL HARQ

DL Multicast HARQ

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
MData : indicate data packet is successfully transmitted in an MHARQ group
MData* : indicate data is failed during transmission in an MHARQ group

Example 2:
DL Multicast HARQ with End-to-end Pre-scheduling

Data : indicate unicast data packet is successfully transmitted
MData : indicate data packet is successfully transmitted in an MHARQ group
MData* : indicate data is failed during transmission in an MHARQ group

Example 3:
UL Multicast HARQ vs. Conventional UL HARQ with hop-by-hop scheduling

Conventional UL HARQ ***UL Multicast HARQ***

Data : indicate unicast data packet is successfully transmitted
Data* : indicate data is failed during transmission

Example 4:
UL Multicast HARQ with End-to-end Pre-scheduling

Data : indicate unicast data packet is successfully transmitted
Data* : indicate multicast data is failed during transmission

Part-3: Dummy HARQ Re-transmission Pattern

Design Principles of Dummy HARQ Re-transmission Pattern

- For each UL/DL multi-hop HARQ channel, MR-BS may pre-allocate bandwidth for links on relay path
- When HARQ burst is corrupted by interference and noise,
  - RS should not forward erroneous HARQ burst to the next hop. Instead, RS may send none by modifying the MAP sent by it
  - However, it is impossible to change the MAP for transparent RSs. So, a station is expecting to receive data from the superordinate station
- To resolve the issue, we propose a dummy HARQ pattern which is used for the pre-allocated transmissions when an RS cannot correctly decode HARQ packet
- The dummy HARQ pattern which is designed for
  - forcing receiver to reply NACK to MR-BS
  - facilitating receiver to perform channel quality measurement
- The dummy HARQ pattern shall not cause any performance degradation on HARQ reception and no impact on the behavior in receiver

Dummy HARQ Re-transmission Pattern Generation

- **The dummy HARQ pattern for an OFDMA symbol may be the following two formations:**
  - **Stuff data with pilot**
    - **Stuff data indicates a specific pattern which will result in an invalid CRC check at the receiver**
  - **Null data with pilot**
    - **For the CQI measurement**

Part-4: Dedicated ACK Channel for Each Hop

The Need of Dedicated ACK Channel for Each RS

- Per UL/DL HARQ channel, MR-BS may allocate one dedicated ACK channel for designated RS along relay path, such that MR-BS can speed up the re-transmission of HARQ packet instead of waiting for full round-trip delay
- The dedicated ACK channel could be selectively assigned to an RS whose air link quality is below a threshold

DL HARQ with Dedicated ACK Channel

- ACK/NACK shall be generated by RS/MS.
- ACK/NACK shall be forwarded to MR-BS by RS.
- RS does not forward erroneous HARQ packet, instead it sends predefined dummy information on relay links.
- If access RS does not have correct packet yet, it
  - generates NACK on behalf of MS
  - replaces MS CID in DL HARQ sub-burst IE as RS CID
- Failure is detected at the 2nd frame. BS can early start retransmissions at the 3rd frame.
- Retransmission occurs on effected links only.

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
Dummy : indicate RS sending the dummy information on HARQ sub-burst

UL HARQ with Dedicated ACK Channel

There are two kinds of ACK/NACK per HARQ channel : **DL ACK/NACK** and **UL ACK/NACK**

- UL ACK/NACK shall be generated by RS and forwarded to BS.
- DL ACK/NACK destining to MS shall be generated by access RS.
- DL ACK destining to RS shall be generated by BS.
- DL NACK destining to RS may be generated by BS.

➲ UL ACK from intermediate RS ***triggers*** BS to send DL ACK to the successor of that RS

trigger

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
Dummy : indicate RS sending the padding bits on HARQ sub-burst

Part-5: Recovery ACK Channel

The Need for Recovery Channel

- ACK/NACK sent from RS to MR-BS may be interfered by channel noise,
  - if error occurs on ACK (ACK is decoded as NACK), it will cause unnecessary retransmissions but not cause system deadlock
  - If error occurs on NACK (NACK is decoded as ACK), it will cause inconsequent retransmission from the RS which does not have correct HARQ packet, and will cause system deadlock
- To resolve the inconsequent retransmission problem, it is required to allocate a recovery ACK channel for the RS which is arranged to retransmit HARQ packet.
  - For saving resource requirement, the recovery channel may be embedded in the dedicated ACK channel or HARQ report channel

Multi-hop DL HARQ w/o recovery ACK channel

- ACK shall be generated by the receiving station, whereas NACK shall be generated by the RS which does not receive correct HARQ packet
- ACK/NACK shall be forwarded to MR-BS by RS
- RS could forward erroneous HARQ packet or predefined dummy information on relay links
- If access RS does not have correct packet yet, it
  a. generates NACK on behalf of MS
  b. replaces MS CID in DL HARQ sub-burst IE by RS CID

5. If error occurs on NACK(RS), BS will schedule inconsequent retransmission from RS to MS.

Data* : indicate data packet is failed during transmission
NACK* : indicate NACK is failed during transmission

Multi-hop DL HARQ w/ recovery ACK channel

- If error occurs on NACK(RS), MR-BS still schedules inconsequent retransmission from RS to MS
- We propose that MR-BS shall allocate a recovery ACK channel to the RS, so that the inconsequent retransmission could be detected at MR-BS by receiving a NACK(RS) from the RS

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission

Multi-hop DL HARQ w/o recovery ACK channel

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission

Multi-hop DL HARQ w/ recovery ACK channel

Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission

Multi-hop UL HARQ w/o recovery ACK channel

There are two ACK/NACK required per UL HARQ channel : **DL ACK/NACK** and **UL ACK/NACK**

- UL ACK/NACK shall be generated by RS and forwarded to MR-BS
- DL ACK/NACK destining to MS shall be generated by access RS
- DL ACK/NACK destining to RS shall be generated by MR-BS
- RS could forward erroneous HARQ packet or predefined dummy information on relay links
- If error occurs on NACK(RS), MR-BS will schedule inconsequent retransmission from RS to MR-BS

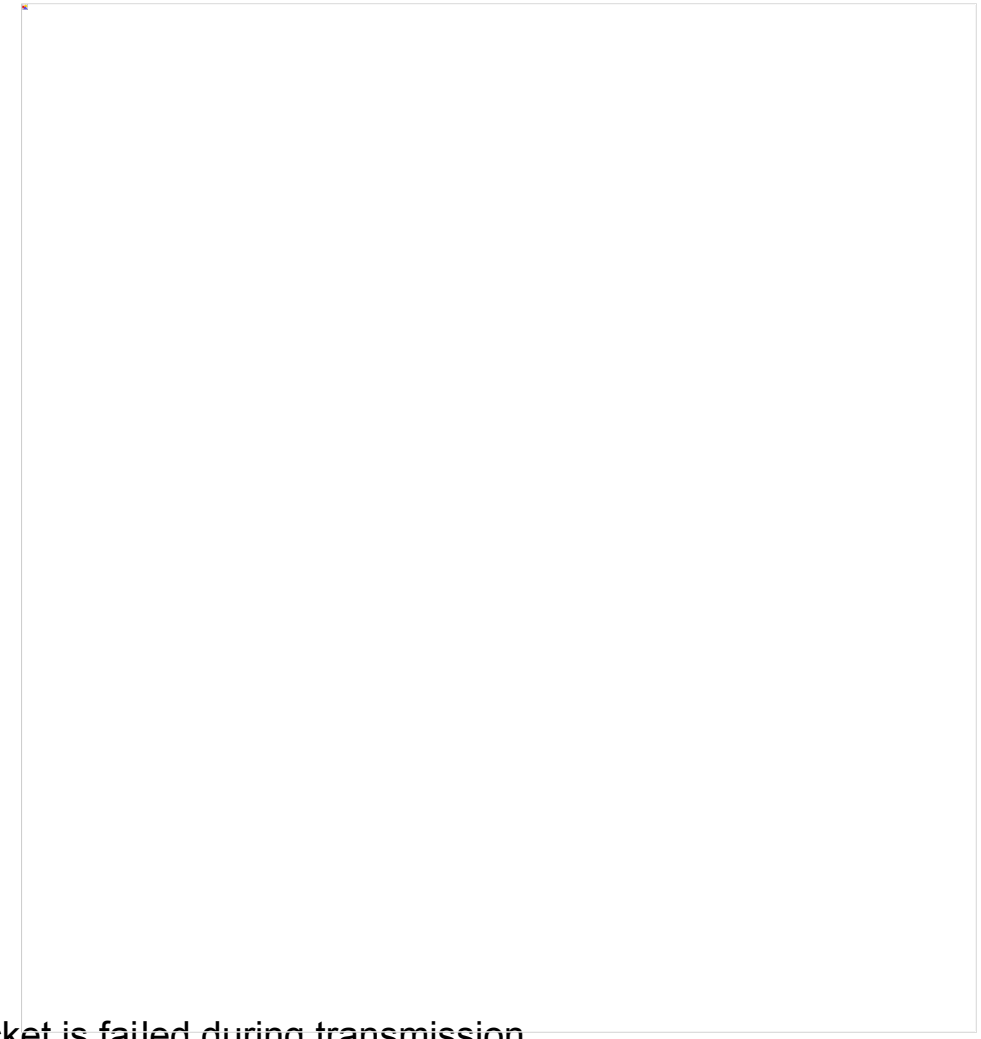
Data* : indicate data packet is failed during transmission
NACK* : indicate NACK is failed during transmission
Dummy : indicate RS sending the padding bits on HARQ sub-burst

Multi-hop UL HARQ w/ recovery ACK channel

- If error occurs on NACK(RS), MR-BS still schedule inconsequent retransmission from RS to MS
- We propose that MR-BS shall allocate a recovery ACK channel to the RS, so that the inconsequent retransmission could be detected at MR-BS by receiving a NACK(RS) from RS

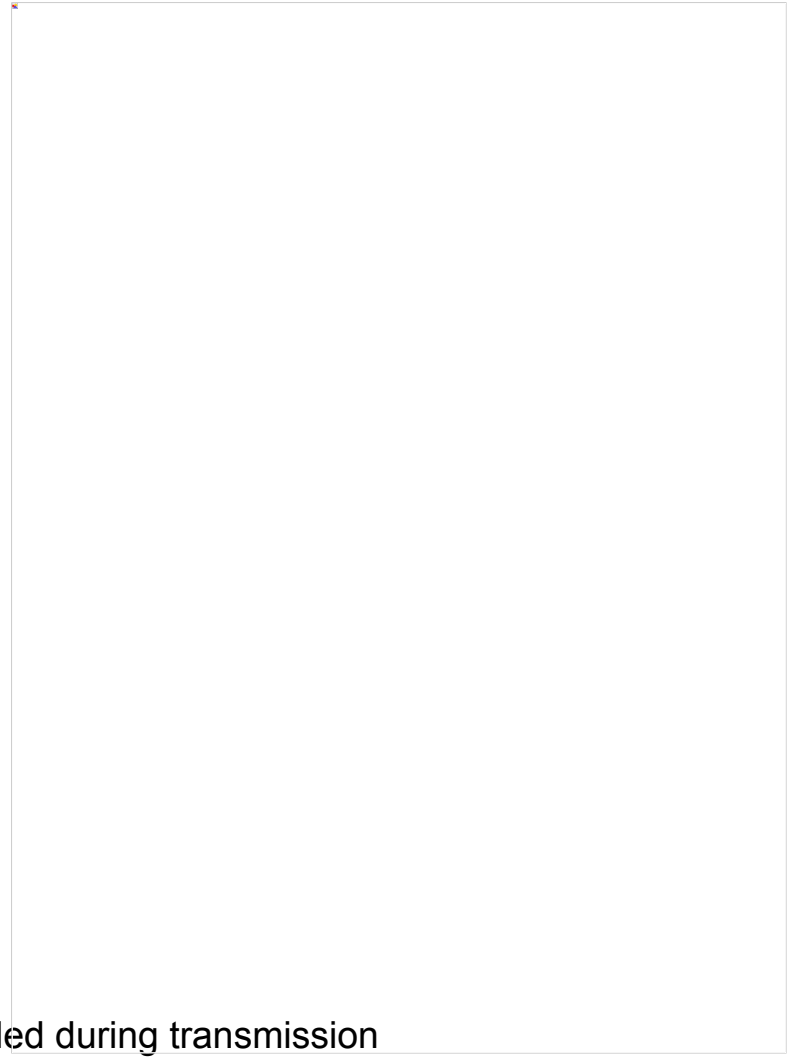
Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission
Dummy : indicate RS sending the padding bits on HARQ sub-burst

Multi-hop UL HARQ w/o recovery ACK channel



Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission
Dummy : indicate RS sending the padding bits on HARQ sub-burst

Multi-hop UL HARQ w/ recovery ACK channel



Data* : indicate data packet is failed during transmission
Data : indicate data packet is successfully transmitted
NACK* : indicate NACK is failed during transmission
Dummy : indicate RS sending the padding bits on HARQ sub-burst

Summary

- **This contribution proposes**
  1) **In multi-hop relay system with pre-scheduling, RS should relay either correct HARQ burst or dummy HARQ pattern**
  2) **A multicast HARQ scheme for transparent RSs to facilitate the HARQ in multihop relay systems**
  3) **Per HARQ channel, MR-BS should allocate one ACK channel to designated RS along the path, or one HARQ report channel to every HARQ channel, or combination of both schemes**
  4) **For each scheduled retransmission from an RS, MR-BS may allocate one recovery ACK channel to the RS in order to eliminate any inconsequent retransmission arrangement caused by erroneously decoded ACK/NACK which introduces inconsistent HARQ state between MR-BS and RS**

- **To adopt the text proposal proposed in the C80216j-07/185r3.doc**