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

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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

2-hop case

<table>
<thead>
<tr>
<th>MR-BS</th>
<th>RS1</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error in Hop #1 Report(01)</td>
<td>DL-MAP (SPID= 1 to RS1)</td>
<td>Data (x)</td>
</tr>
<tr>
<td>HARQ status report(01)</td>
<td>DL-MAP (remove IE to MS)</td>
<td></td>
</tr>
<tr>
<td>Error in Hop #2 Report(10)</td>
<td>DL-MAP (SPID= 2)</td>
<td>Data</td>
</tr>
<tr>
<td>HARQ status report(10)</td>
<td>DL-MAP (SPID=1)</td>
<td>Data (x)</td>
</tr>
<tr>
<td>No error in Hop #2 Report(00)</td>
<td>DL-MAP</td>
<td>Data</td>
</tr>
<tr>
<td>HARQ status report(00)</td>
<td>ACK</td>
<td></td>
</tr>
</tbody>
</table>

3-hop case

<table>
<thead>
<tr>
<th>MR-BS</th>
<th>RS1</th>
<th>RS2</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error in Hop #1 Report(00)</td>
<td>DL-MAP (SPID= 1 to RS1)</td>
<td>Data (x)</td>
<td>DL-MAP (remove IE to RS2 and MS)</td>
</tr>
<tr>
<td>HARQ status report (01)</td>
<td>Earlier Retransmission</td>
<td>HARQ status report (empty)</td>
<td>ACK (empty)</td>
</tr>
<tr>
<td>Error in Hop #2 Report(01)</td>
<td>DL-MAP (SPID= 2 to RS1)</td>
<td>Data</td>
<td>DL-MAP (SPID=1 to RS2)</td>
</tr>
<tr>
<td>HARQ status report(01)</td>
<td>HARQ status report(01)</td>
<td>HARQ status report(01)</td>
<td>ACK (empty)</td>
</tr>
<tr>
<td>Error in Hop #3 Report(11)</td>
<td>DL-MAP</td>
<td>Data</td>
<td>DL-MAP (SPID = 1 to MS)</td>
</tr>
<tr>
<td>HARQ status report(11)</td>
<td>HARQ status report(11)</td>
<td>HARQ status report(11)</td>
<td>NAK</td>
</tr>
<tr>
<td>No Error in Hop #3 Report(00)</td>
<td>DL-MAP</td>
<td>Data</td>
<td></td>
</tr>
<tr>
<td>HARQ status report(00)</td>
<td>ACK</td>
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2-hop case

3-hop case

MR-BS
RS1
RS2
MS

Error in Hop #1
Report(01)

DL-MAP (SPID= 1 to RS1)

Data (x)

DL-MAP (remove IE to MS)

HARQ status report(01)

Error in Hop #2
Report(10)

DL-MAP (SPID= 2)

Data

DL-MAP (SPID=1)

Data (x)

NAK

HARQ status report(10)

No error in Hop #2
Report(00)

DL-MAP

DL-MAP (SPID=2 to RS1)

Data

ACK

HARQ status report(00)

Error in Hop #3
Report(11)

DL-MAP

DL-MAP (SPID=2 to RS2)

Data

ACK

HARQ status report(11)

No Error in Hop #3
Report(00)

DL-MAP

DL-MAP (SPID = 2 to MS)

Data

ACK

HARQ status report(00)
# Flow Diagram for DL HARQ with Centralized Scheduling

## 2-hop case

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<tr>
<th>MR-BS</th>
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<tbody>
<tr>
<td>UL-MAP (SPID= 1 to RS)</td>
<td>HARQ status report(1)</td>
<td>No need for HARQ report to RS1</td>
</tr>
<tr>
<td>Error in Hop #2 Report (1)</td>
<td>NAK</td>
<td>Data</td>
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## 3-hop case

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<tbody>
<tr>
<td>UL-MAP (SPID= 1 to RS1)</td>
<td>UL-MAP(SPID=1 to RS2)</td>
<td>UL-MAP (SPID=2)</td>
<td>Data</td>
</tr>
<tr>
<td>Error in Hop #3 Report (11)</td>
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<td>No error in Hop #2</td>
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<td>UL-MAP(SPID=1 to RS2)</td>
<td>UL-MAP (SPID=2)</td>
<td>Data</td>
</tr>
<tr>
<td>Error in Hop #3 Report (11)</td>
<td>Error in Hop #2 Report (10)</td>
<td>No error in Hop #2</td>
<td>ACK</td>
</tr>
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</table>

## Error in Hop #2 Report (1)

- MR-BS to RS1: HARQ status report(1)
- RS1 to MS: Data
- MS to RS1: NAK
- RS1 to MR-BS: Dummy

## Error in Hop #3 Report (11)

- MR-BS to RS1: HARQ status report(11)
- RS1 to RS2: Data
- RS2 to MS: ACK
- MS to RS2: NAK
- RS2 to MR-BS: Dummy
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-1 of 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**

<table>
<thead>
<tr>
<th>Conventional DL HARQ</th>
<th>DL Multicast HARQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Conventional UL HARQ</th>
<th>UL Multicast HARQ</th>
</tr>
</thead>
</table>

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
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** destinining to MS shall be generated by access RS.
- **DL ACK** destinining to RS shall be generated by BS.
- **DL NACK** destinining to RS may be generated by BS.

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

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
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Multi-hop UL HARQ w/ recovery ACK channel

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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