Relay Path Management in multi-hop relay network

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Purpose:
To propose path management for IEEE802.16j

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Mechanism of relay path management
- One relay path per Relay Station
- One relay path per Service
- Combination of both, connection sharing on relay links

Mechanism of MAC PDU forwarding
- Forwarding table driven in RS
- Header embedded path information
One relay path per Relay Station

- All traffic from one RS will be carried over one relay path
- Multiple services mapped to one connection in each relay link
- Simple to implementation
- Less resource consumption
- Better performance on mobile RS
- Problems to handle different QoS constraints on data connections
One relay path per service (1/2)

Same physical relay path and different logical relay paths

Different physical and logical relay paths
One relay path per service (2/2)

- Relay path for data traffic could be setup through DSA-REQ/RSP

- The path information could be piggy back in DSA-RSP or sent with separate CID mapping message.
  - Piggy back mode:
    - RS parse DSA-RSP and update its CID forwarding table accordingly.
    - RS Relay DSA-RSP.
  - Separate mode:
    - RS relay DSA-RSP
    - RS parse CID mapping message and update its CID forwarding table accordingly.
    - CID mapping message could undergo path different from DSA-RSP path.
Combination of both, connection sharing on relay links

• Rationales
  – Satisfy all QoS requirements from access link
  – Reduce amount of connections on relay links
• Connection sharing on relay links for
  – Management connections
    • Management connections from MS are transported via management connection of RS
      – MS basic CID via RS basic CID
      – MS primary management CID via RS primary management CID
      – MS secondary management CID via RS secondary management CID
  – BE (best effort) data connections from MSs may be merged on one RS BE connection
  – Several non-BE data connection from access links may by be merged to one or more RS connection according to QoS constrains
    • N number of data connections on access link
    • M number of data connections on relay link
    • N >= M >= 1
Example: Connection Reduction on Relay Link

• Assumption:
  – 50 MS are connected to one RS
  – Every MS has 4 connections:
    • 2 management connections, basic and primary management
    • 2 Data connections, one BE for Web browsing, one rtPS for VoIP
• One relay path per service would result in:
  \(50 \times 4 = 200\) connections on relay link
• Path reduction:
  – Management connections of MS are relayed over the management connection of RS, no additional connections
  – All BE connections of MS are relayed over one BE relay connection, only one additional connection
  – rtPS connections of MS are relayed over one or little bit more rtPS connections on relay link, depending on the QoS constrains of the rtPS connections
• Totally 2 (or little bit more) additional connections on relay link
Each RS maintains a CID forwarding table for MAC PDU forwarding.

CID Mapping between incoming and outgoing CIDs could be 1:1, M:1, 1:N and M:N.

Action could be En-cap, De-cap, Translation etc.
Table Driven for MAC PDU forwarding (2/2)

(1) En-Cap Action

(2) De-Cap Action

(3) Translation Action
MAC PDU forwarding by Header Embedded Path Information

MAC PDU contains path information
- MAC PDU contains generic messages header as defined in 802.16e-2005
- Message contains additional subheader as defined in 802.16e-2005 path subheader type and layout definition to be done in 802.16j
- Path subheader contains: CID list which defines the connection path
- and further information elements
  - CNT defines count of CID’s in list
  - HC defines hop count
  - LS List/Stack flag indicates if subheader shall be used as list (wrap around) or stack (shift-remove)
Embedded path information for MAC PDU forwarding
Per Hop Header Processing

**MAC Messages with subheader CID list, List wrap around**

Downlink forwarding:
1. Append header CID at the end of the CID list
2. Remove first CID from list and set this as the new CID in header
3. Update subheader IE's and HCS

**MAC Messages with subheader CID stack, Stack processing**

Forwarding:
1. Remove first CID from list and set this as the new CID in header
2. Update subheader IE's and HCS
MAC PDU Forwarding Example: MR-BS <-> MS management communication via 3 RS

MAC management communication : BS to MS, BS sends MAC management message to MS via management connection, (Basic, Primary or Secondary)

0: MR-BS prepare MAC PDU with CID list in subheader according to topology database
1: RS stores stack, removes subheader to get an 802.16 compliant MAC PDU, and sends it to MS
2: MS sends reply MAC management message using its management CID
3: RS3 receives MAC PDU, performs a lookup in its stored CID list database, (using M-CIS MS as an index ), builds subheader perform an uplink wrap around and sends MAC PDU to next hop
4: RS performs CID list wrap around for uplink

Management communication : Same CID's for downlink and uplink, access relay station (RS3) can "reuse" CID path list from downlink management path
One relay path per service

- Relay path for data traffic could be setup through DSA-REQ/RSP handshaking procedure which could be done on the relay path for management message.
- The path information could be transported in the subheader.
- Subheader with incorporated path information is inserted at access RS(1)
- Path information at access RS is used from previous management messages
- DSA-REQ/RSP is forwarded according the subheader information, CID and subheader is updated on every hop as described on slide 13
- With path information in subheader MMR-BS can determine the originator of the DSA-REQ
Recommendation on MAC PDU forwarding

- Table driven in RS
  - More suitable for data connections

- Embedded path information
  - More suitable for management connections
  - Fast forwarding, no forwarding table lookup
  - No path setup or configuration messages, receiving RS in downlink can reuse path information for uplink send
  - Receiving RS or MR-BS can use receive path information for originator determination
Summary

• Scheme of relay path management in 802.16j
  – Three mechanisms of relay path for data traffic
    ✓ One relay path per Relay Station
    ✓ One relay path per Service (shared paths)
    ✓ Mix mode, partly relay paths per service and shared paths
  – Two Mechanisms of MAC PDU forwarding
    ✓ Table driven in RS
    ✓ Embedded path information

• Benefits
  – Flexible due to control/data path separation
  – Easy for Multi-path routing and cooperative relay
  – Compatible with existing connection setup in 802.16
  – No new header format and header processing
  – Reduction of relay link connections
• **Piggyback mode:**
  – Need DSA-RSP message extension (with ESF=1)

• **Separate mode**
  – No modification to DSA-RSP
  – Need a new-defined CID mapping message
Backup_Slide 7

En-cap

De-cap

En-cap
Backup Slides_Slide 7

• Typically, for control/management message
  – Access RS would take en-cap/de-cap action to relay uplink/downlink control/management message
  – Intermediate RS would take translate action

• Typically, for data message
  – Access RS would take translate action
  – Intermediate RS would take translate action
## Backup-DSA_RSP Extension

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
<th>Value</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>[145/146].47</td>
<td>variable:</td>
<td>Compound:</td>
<td>DSx-REQ</td>
</tr>
</tbody>
</table>
|               | 6n         | For(j=0; j<N_RS; j++){
|               |            | 24bits: RS_ID                                                        | DSx-RSP        |
|               |            | 8bits: Action                                                        | DSx-ACK        |
|               |            | 16bits: OutgressCID                                                  |                |
| Action:       |            | Indicate RS                                                          |                |
| how to relay  |            | the ingress CID                                                      |                |
| CID           |            | 0x00: CID Translate                                                  |                |
|               |            | 0x01: CID Encap                                                      |                |
|               |            | 0x02: CID Decap                                                      |                |
|               |            | 0x03: Reserved                                                       |                |
|               |            | 0x04: CID Header Wrap                                               |                |
|               |            | 0x05: CID Header Stack                                              |                |
|               |            | 0x06: CID Header Add List                                           |                |
|               |            | 0x07~0xFF: Reserved                                                  |                |
### Backup_CID Mapping Message

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CID_MAP_Message_format()</td>
<td>--</td>
<td>CID mapping message</td>
</tr>
<tr>
<td>Management Message Type=80</td>
<td>8 bits</td>
<td>--</td>
</tr>
<tr>
<td>N_RS</td>
<td>4 bits</td>
<td>Number of RS to relay the service</td>
</tr>
<tr>
<td>For(j=0; j&lt;N_RS; j++){</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>RS ID</td>
<td>24 bits</td>
<td>Identify RS</td>
</tr>
<tr>
<td>Action</td>
<td>3 bits</td>
<td>Indicate RS how to relay the ingress CID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>000: CID Translate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>001: CID Encap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>010: CID Decap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>011: Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100: CID Header Wrap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>101: CID Header Stack</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110: CID Header Add List</td>
</tr>
<tr>
<td></td>
<td></td>
<td>111: Reserved</td>
</tr>
<tr>
<td>Outgress CID</td>
<td>16 bits</td>
<td>CID that to be put into the header of MAC PDU which is carried on the ingress CID. Only for action 000, 001.</td>
</tr>
<tr>
<td>}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLV encoded information</td>
<td>variable</td>
<td>--</td>
</tr>
<tr>
<td>Padding</td>
<td>variable</td>
<td>If needed for alignment to byte boundary</td>
</tr>
<tr>
<td>}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Backup_Route and CID mapping

Select Route: 1->2->3->4 according to resource and requirement
Allocate CIDs for access link and relay link
Route-to-CID binding

CID Path: 106, 300, 500

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Count</th>
<th>Next</th>
<th>Bandwidth</th>
<th>Delay</th>
<th>Other Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>..</td>
<td>2</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>..</td>
<td>3</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>..</td>
<td>4</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>

BS Routing Table

RS2 CID Forwarding Table

<table>
<thead>
<tr>
<th>In CID</th>
<th>Out CID</th>
<th>Action</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>From RS1</td>
<td>106</td>
<td>300</td>
<td>Mapping</td>
</tr>
</tbody>
</table>

RS1 CID Forwarding Table

<table>
<thead>
<tr>
<th>In CID</th>
<th>Out CID</th>
<th>Action</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>From MS</td>
<td>100</td>
<td>106</td>
<td>Mapping</td>
</tr>
</tbody>
</table>