An Framework for Multi-hop Path Management in MMR Networks

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Path Management Framework

- Central Path management in MR-BS
- Path and connection database in MR-BS
- Forwarding in RS
- Forwarding database in RS
Path Management in MR-BS

- Path management:
  - is a functional entity inside MR-BS
  - controls the path management in its subordinate network, all connected RS and MS
  - incorporates database which stores all connection relevant data's
  - decides forwarding method for the connections
  - includes connection path setup, change and delete
  - sends path management related MAC messages to subordinates RS and MS
**Path Management in RS**

- RS contains and maintains forwarding database for MAC PDU forwarding
- Forwarding decision is taken according to:
  - database lookup
  - Header subheader information
- Forwarding database contains information like:
  - Relation of incoming CID to outgoing CID
  - Relation of incoming CID to outgoing CID list
  - Type of forwarding method
- Forwarding databases are updated by information:
  - From MAC management PDU send by path management
  - Derived from received DSx management messages
  - From MAC header and subheader information elements
Forwarding methods

- **CID mapping**
  - CID may change from hop to hop
  - RS inserts the new CID value in the header and adapts further information fields in the header if necessary
  - Determination of the new CID is done by a forwarding database lookup.

- **Transparent forwarding**
  - CID keeps the same along the path between the logical communication endpoints

- **Tunneled forwarding**
  - CID may change from hop to hop
  - In uplink direction, relaying RS leaves header of received MAC PDU unchanged and prepends a new header
  - Inverse procedure in downlink direction
  - Determination of the new CID is done by a forwarding database lookup
  - The number of headers is given by the number of hops.

- **Header subheader processing**
  - CID may change from hop to hop
  - Path between the communication endpoints is defined by the CID in the MAC PDU header and a CID list in the subheader
  - Subheader insertion or removal at access RS
  - RS performs CID list wrap around in header and subheader
  - No database lookup in intermediate RS
Decision of Forwarding Methods

• Path management in MR-BS selects an appropriate forwarding method for a connection according to the following constrains:
  – QoS constrains of the connection
  – Type of connection (data or management)
  – Available resources in MMR

* Algorithms or configurations are implementation issues and not part of standard
Path management: Forwarding Methods

- MAC PDU forwarding
  - Forwarding table driven in RS
    - Transparent forwarding
    - CID switched forwarding
    - Tunneled forwarding
  - Header embedded path information
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.
Forwarding Database Driven MAC PDU Forwarding (2/2)

(1) En-Cap Action (Tunneling)

(2) De-Cap Action (Tunneling)

(3) Translation Action (CID mapping)
Header/Subheader driven 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)

After network entry of MS, BS sends a first MAC management message to MS using a management CID of MS
0: MR-BS prepare MAC PDU with CID list in subheader according to topology database
1: RS3 stores stack, removes subheader to get an 802.16 compliant MAC PDU, and sends it to MS
2: RS3 receives MAC PDU, perform a lookup in its stored CID list database, (using M-CIS MS as an index), build subheader perform an uplink wrap around and sends MAC PDU to next hop
3: MS sends reply MAC management message using its management CID
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
MAC PDU Forwarding by Header and Subheader embedded Path Information (1/2)

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)
MAC PDU Forwarding by Header and Subheader embedded Path Information (2/2)

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

- **Uplink forwarding:**
  1. Prepend header CID at the begin of the CID list
  2. Remove last 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
Example: Path setup 1/3

- Management message transport by transparent relaying
- Data path forwarding by CID mapping
- Optional intermediate connection setup
Example: Path Setup 2/3

- Management message transport by header/subheader forwarding
- Data path forwarding by CID mapping

![Diagram showing path setup with MS, RS1, RS2, and MR-BS nodes, with labeled messages DSA-REQ, DSA-RSP, DSA-ACK, and CID mapping icons.]

- Path subheader insertion and CID wrap around
- CID wrap around and path subheader removal
- CID wrap around
- CID mapping
Example: Path Setup 3/3

- Management message transport by tunneling
- Data path forwarding by CID mapping
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
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
Summary

• Central Path management in MR-BS
• Forwarding in RS driven by path management in MR-BS
• Several forwarding mechanisms configured by path management according to connection constrains
• Forwarding in RS according to forwarding database and/or header/subheader information
Backup Slides
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 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
# 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>000: CID Translate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>001: CID Encap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>010: CID Decap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>011: Reserved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100: CID Header Wrap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>101: CID Header Stack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>110: CID Header Add List</td>
<td></td>
<td></td>
</tr>
<tr>
<td>111: Reserved</td>
<td></td>
<td></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>Src</th>
<th>Dest</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>
Backup Slides_Slide 5

• Piggyback mode:
  – Need DSA-RSP message extension (with ESF=1)

• Separate mode
  – No modification to DSA-RSP
  – Need a new-defined CID mapping message
• 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
## 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: 6n</td>
<td>Compound: For(j=0; j&lt;N_RS; j++) {</td>
<td>DSx-REQ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24bits: RS_ID 8bits: Action 16bits: OutgressCID }</td>
<td>DSx-RSP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action: Indicate RS how to relay the ingress CID</td>
<td>DSx-ACK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0x00: CID Translate 0x01: CID Encap 0x02: CID Decap</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0x03: Reserved 0x04: CID Header Wrap 0x05: CID Header Stack</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0x06: CID Header Add List 0x07~0xFF: Reserved</td>
<td></td>
</tr>
</tbody>
</table>