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Re:	IEEE 802.16j-06_034: “Call for Technical Proposals regarding IEEE Project P802.16j”	
Abstract	Define path management framework	
Purpose	For text changes in emerging amendment of IEEE 802.16e-2005 to support MMR functionality.	
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Multi-hop Path Management Framework in MMR Networks

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1 Introduction

This document is to describe path management framework as an input for call for contribution of 802.16j task group. The terminologies defined in IEEE 802.16j-06/014r1 are used to support path management in MMR relay topology.

In this document, we propose a flexible framework together with corresponding messages and procedures to support the path management (path setup/change/delete). The framework facilitates QoS provision, multi-path routing and data/control plane separation in MMR networks and be fully compatible with 802.16 on the access link.

The contribution covers the following text descriptions:

Connection path management related to MS to RS connection, RS to RS connection and RS to MR-BS connection

CID and Relay path binding

Relay operations involving the modification of CIDs via CID mapping

2 Path Management

Refer to figure 1, along a relay path <RS(1), RS(2), …, RS(n), MR-BS>, a RS may transparently relay or tunnel the message between MS and MR-BS. When using tunneling, connection switching path (CSP) for a particular MAC PDU that is sent via CID C(0) on the logical access link is defined as the sequence of CIDs <C(1), C(2), …, C(n)>:
1. For all i, 1<=i<=n, C(i) is the CID allocated to identify a transport connection between MR-BS and RS(i).

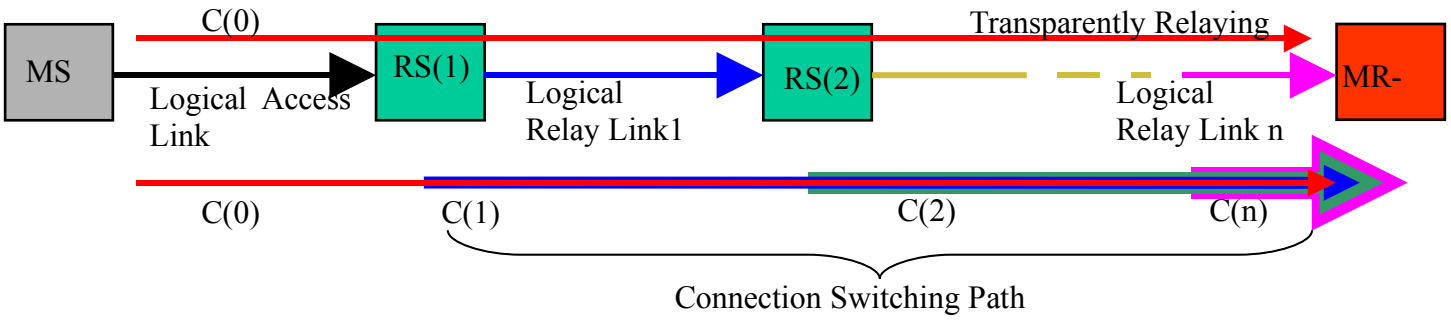

Fig.1 Connection Switching Path, Logical Relay Link and Connection

In fact, CSP reflects the CID mapping information between ingress and outgress CID. The main purpose of introducing CSP in MMR is to enhance QoS provision and facilitate advanced features such as load balancing and multi-path routing in such network. Either centralized or distributed control method should benefit from the proposed framework.

CSP may be managed via DSx message (or optionally, additional new messages) exchange between MMR-BS and access RS. RS may choose transparently relaying for the message exchange in CSP management. After a CSP is setup for a service flow, RS can then tunnel the service flow in the CSP.

2.1 Path Management via DSx messages

In MMR, after initial ranging and network entry procedures, Both MS and RS shall get a primary CID. MS can then request via DSA-REQ message for a service connection for the service communication between it and MR-BS. A connection switching path (CSP) may be setup during the service flow creation procedure. Similarly, CSP change and deletion may be initiated by the service flow change and deletion procedure, respectively.

The overall operation related to a new CSP setup can be described as following:

MS requests a service connection for a service flow via DSA-REQ message

Access RS relays the management message to MR-BS.

Due to the requirement of security sub-layer in 802.16e, the management messages are sent in the clear text and are protected by CMAC/HMAC, so modification on the MAC PDU header/extended sub-header/sub-header will not be possible. In such cases, access RS may relay the message transparently or tunnel the message.

When relaying the DSA-REQ message transparently, access RS shall keep the DSA-REQ message in its originally received form when relaying to MR-BS.

When tunneling the DSA-REQ message, access RS shall encapsulate the MS's DSA-REQ in its own DSA-REQ message that is sent on the access RS's primary CID.

When relaying the DSA-REQ message via extended path subheader, access RS changes the CID in the header and inserts a path subheader. The CID's in the header and subheader define the connection switching path CSP. The information for the CSP are taken from previously stored database.

Intermediate RS relays the message to MR-BS.

Due to the requirement of security sub-layer in 802.16e, the management messages are sent in the clear text and are protected by CMAC/HMAC, so modification on the MAC PDU header/extended sub-header/sub-header will not be possible. In such cases, intermediate RS may relay the message transparently or tunnel the message.

When relaying the DSA-REQ message transparently, intermediate RS shall keep the received DSA-REQ message in its originally received form when relaying to MR-BS.

When tunneling the DSA-REQ message, intermediate RS shall encapsulate the received DSA-REQ in its own DSA-REQ message that is sent on the intermediate RS's primary CID.

When relaying the DSA-REQ message via extended path subheader, intermediate RS warps around the CID's in the header and subheader in a defined manner. After that the message contains the correct CID for forwarding without any table lookup and the message is send to the next hop.

MR-BS receives the DSA-REQ message. MR-BS determines the originator of the message by tunnel encapsulation or CID value if the DSA-REQ message was sent in transparent mode. The latter case requires an unambiguous assignment of CID's for that purpose; relay connection sharing is not allowed in this case. After that,

If the DSA-REQ message is transparently relayed by RSs, MR-BS shall allocate a service CID A for the MS to carry the service flow and also determine a connection switching path (CSP) for it. If MR-BS can find an existing CSP suitable for the purpose, MR-BS may notify corresponding RSs on the relay path of the CSP path information via extended DSx message or new defined Path Management message. If MR-BS can not find an existing CSP suitable for the purpose, MR-BS may initiate CSP setup by sending extended DSx message or new defined Path Management message to corresponding RSs on the relay path to request for transport connections. MR-BS shall also bind the CSP with the relay path that is stored in the routing table. Refer to figure 2,

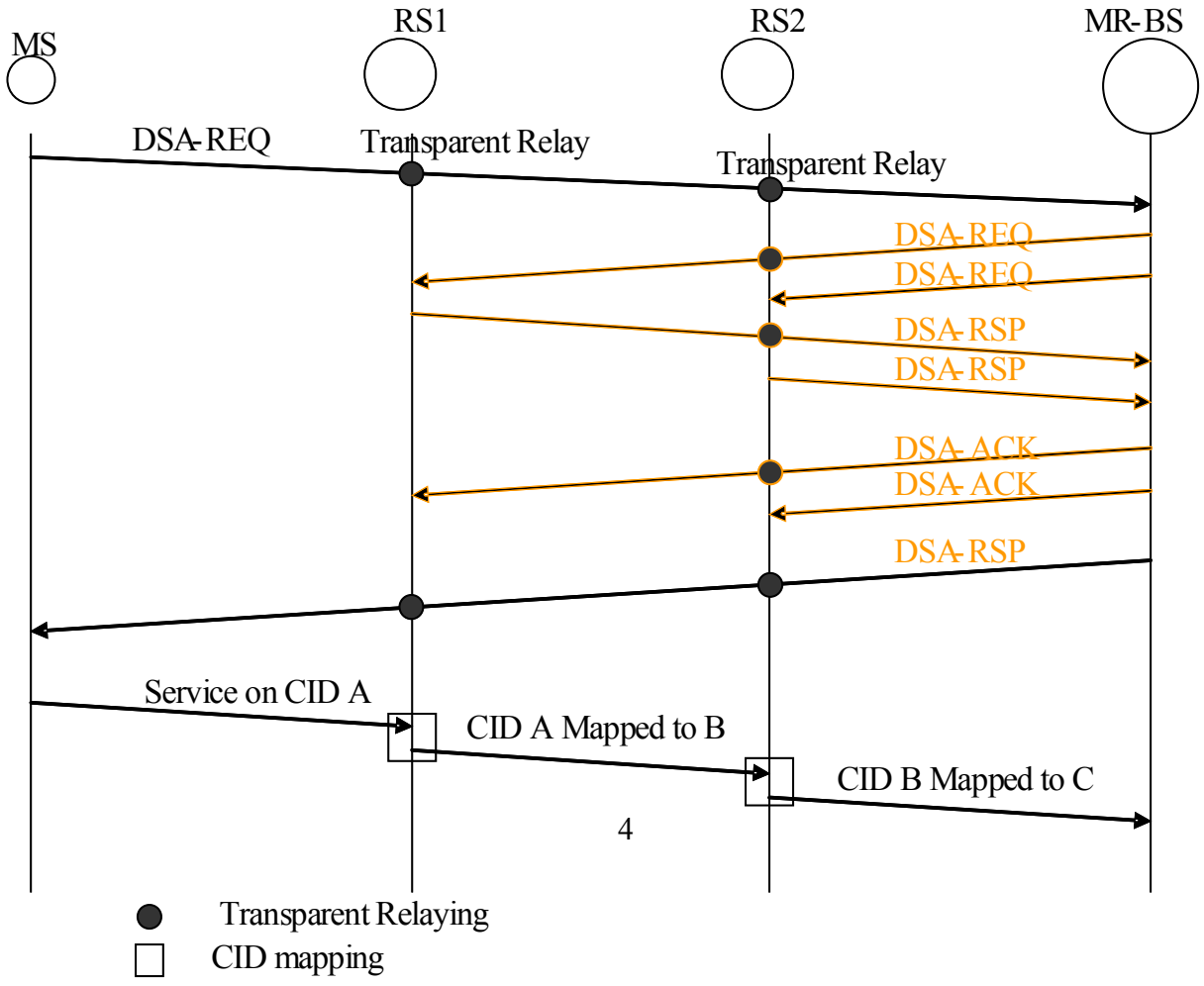

Fig.2. MR-BS initiated CSP setup triggered by MS initiated DSA-REQ with transparent forwarding

MS sends DSA-REQ to MR-BS to request a service connection for a service flow *SF*, access RS (RS1) and intermediate RS (RS2) transparently relay the DSA-REQ message until it reaches MR-BS.

MR-BS allocates a service CID A for the *SF*, and chooses a connection switch path (CSP) for it. If such CSP does not exist, MR-BS will create a new CSP for it. The CSP may be identified by a Path-ID and reflect the CID mapping information, for example, on a relay path <RS1, RS2>, a CSP <B, C> for service connection A means the traffic on CID A shall be mapped onto CID B in RS1 and the traffic on CID B shall be mapped onto CID C in RS2.

MR-BS shall notify the corresponding RSs on the relay path of the CSP and corresponding action for the service CID A. The CSP path information and related action may be carried in the DSA-REQ message initiated by MR-BS. In such case, 802.16 standard DSA-REQ message shall be extended. Optionally, MR-BS may use new defined Path Management messages to notify the CSP information and action. When MR-BS uses extended DSx message to notify such information, after the 3-way handshake, the RSs on the relay path shall know how to forward MAC PDU, for example, for a CSP <CID B, CID C>,

MR-BS sends extended DSA-REQ to RS1 to request for a transport CID B to relay CID A, also, MR-BS sends extended DSA-REQ to RS2 to request for a transport CID C to relay CID B

RS shall use CSP path information to relay a MAC PDU. The CSP path information could be locally stored in RS's CID forwarding table or derived directly from MAC PDU header/extended sub-header/sub-header.

If CSP path information is stored in RS's CID forwarding table, after standard DSA-RSP and DSA-ACK exchange, access RS (RS1 in the figure) shall update its CID forwarding table such that service on CID A shall be mapped on CID B and RS2 shall update its CID forwarding table such that service on CID B shall be mapped on CID C. The CID forwarding table stores the CID mapping information between ingress and outgress CID. Table 1 depicts an example of the CID forwarding table. When a RS get a MAC PDU on an ingress CID, it will look against the ingress CID in the CID forwarding table and take corresponding action to forward the MAC PDU. The CID forwarding table may support various actions. Translation means swapping the ingress CID in the MAC PDU to an outgress CID. Encapsulation means tunneling the MAC PDU on an outgress CID, de-capsulation means de-tunneling the MAC PDU and no action means directly/transparently relaying it. Multiple different ingress CID can be encapsulated in same outgress CID. The actions indicated by CID forwarding table may be accompanied by other necessary operations such as HCS re-calculation.

Tab.1. CID forwarding table

In case of forwarding via MAC PDU

Ingress CID	Outgress CID	Action Type	Next Hop (Optional)
10	40	Translation	XX
20	50	Encapsulation	XX
30	50	Encapsulation	XX
100	105	Encapsulation	XX
105	---	De-capsulation	XX
500	Same	Transparent relay	XX
600	620	Path subheader insertion/removal	XX

header/extended sub-header/sub-header, the CSP information is stored only in access RS and MR-BS. In MR-BS the CSP information is generated by the centralized path management in the MR-MS. In the access RS the CSP information is get from MAC management messages or derived from received header/subheader information. The intermediate RS's needs no CSP information. Refer to figure 3,

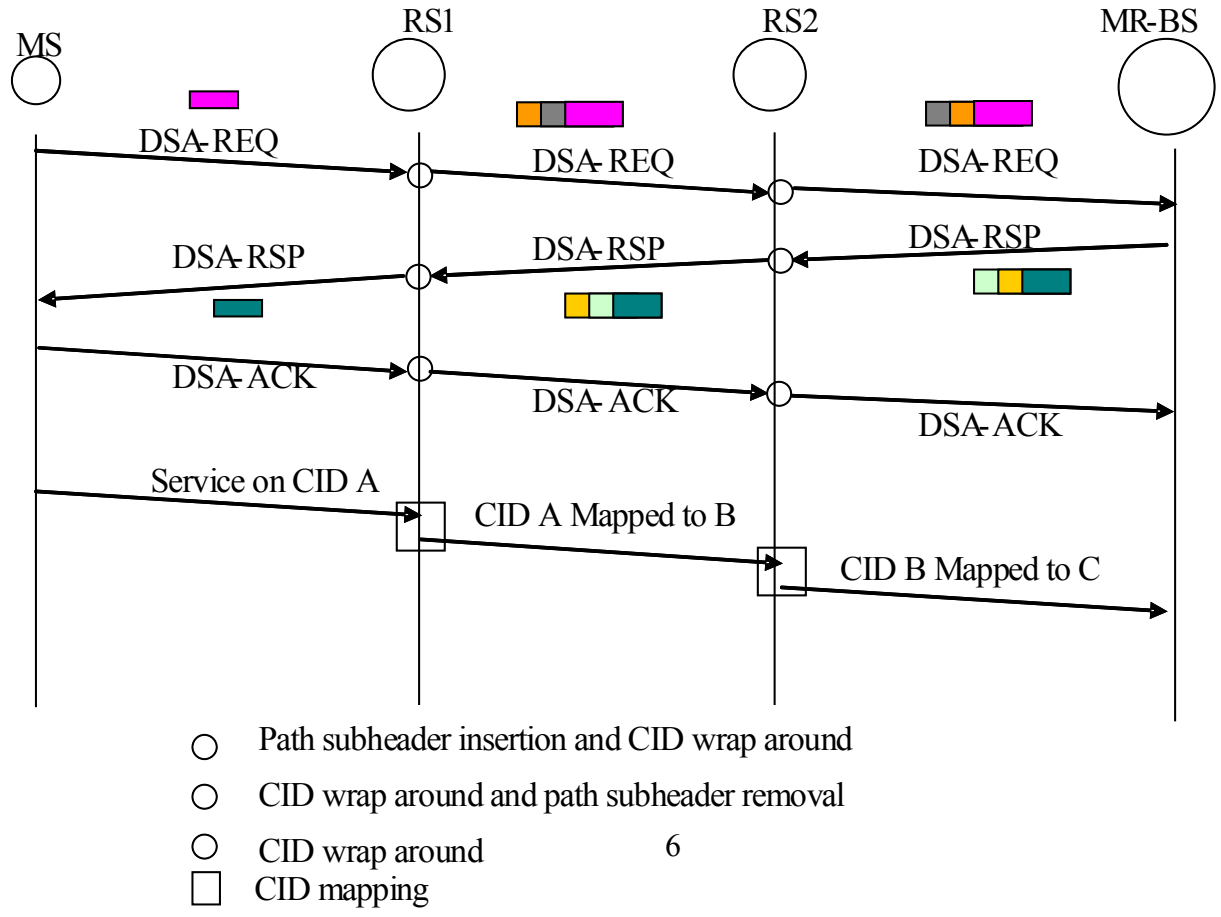

Fig.3. MR-BS initiated CSP setup triggered by MS initiated DSA-REQ with path subheader forwarding

MR-BS responds to MS with DSA-RSP message which is carried on the MS's primary CID

After getting the DSA-RSP, MS can then use the CID A to carry the service flow.

Access RS gets the MAC PDU sent by MS on the service connection CID A, processes it according to its CID forwarding table

Intermediate RS gets the MAC PDU sent by RS on the connection CID B, processes it according to its CID forwarding table or MAC PDU header/extended sub-header/sub-header.

If CSP path information is stored in the CID forwarding table, intermediate RS maps the ingress CID (CID B in the figure) to a transport CID (CID C in the figure)

If CSP path information is derived from the MAC PDU header/extended sub-header/sub-header, intermediate RS does not need CID forwarding table to relay traffic. Instead, it can use the MAC PDU itself to relay it.

MR-BS gets the MAC PDU sent by intermediate RS on the connection CID C, parses to get the original MAC PDU sent by MS on the connection CID A.

If the DSA-REQ message is encapsulated by RSs when relaying, MR-BS shall allocate a service CID A for the MS to carry the service flow and also determine a connection switching path (CSP) for it. If MR-BS can find an existing CSP suitable for the purpose, MR-BS may notify corresponding RSs on the relay path of the CSP path information via encapsulated DSx message or new defined Path Management message. If MR-BS can not find an existing CSP suitable for the purpose, MR-BS may initiate CSP setup by sending encapsulated DSx message or new defined Path Management message to corresponding RSs on the relay path to request the transport connections. MR-BS shall also bind the CSP with the relay path that is stored in the route table. Refer to figure 4.

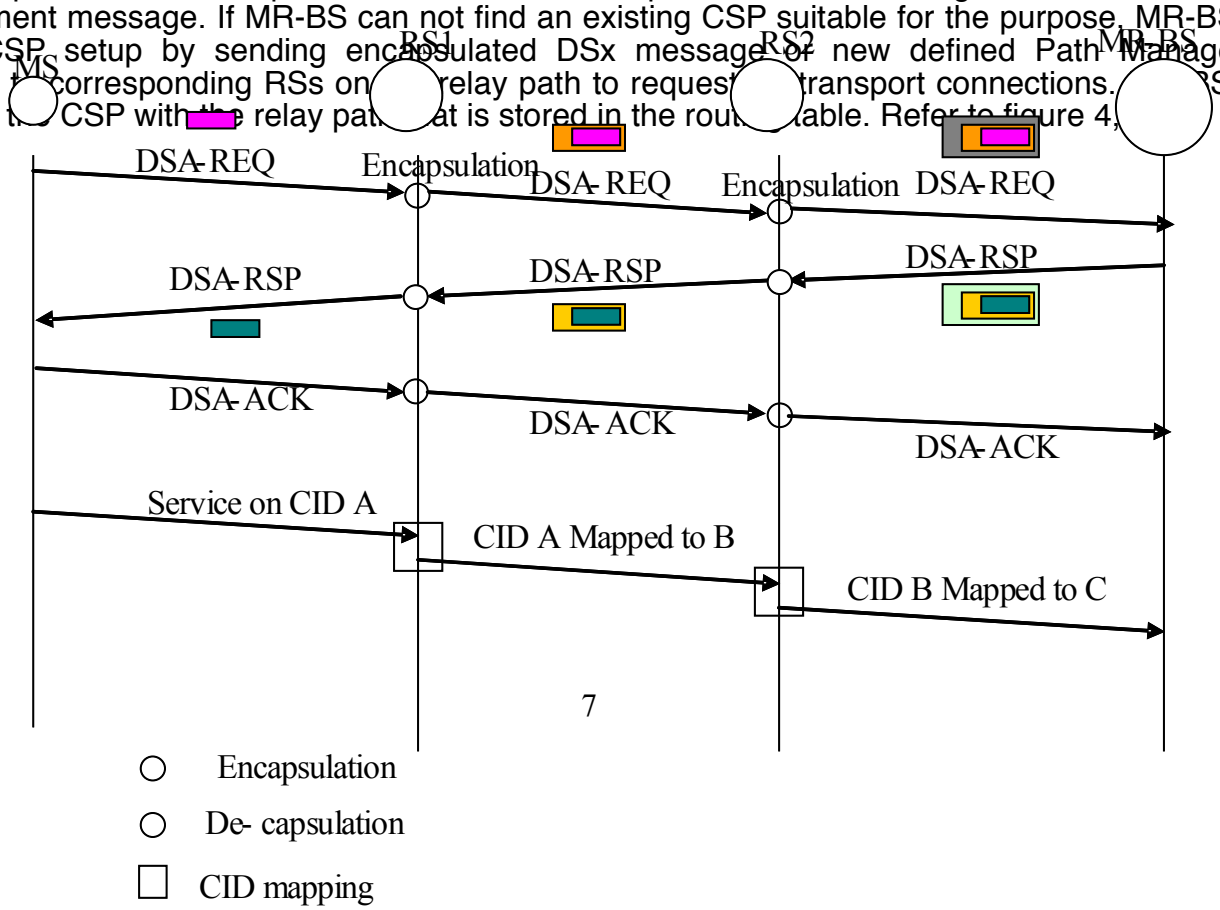

Fig.4. MR-BS initiated CSP setup triggered by MS initiated DSA-REQ with tunneled forwarding

MS sends DSA-REQ to MR-BS to request a service connection for a service flow *SF*, access RS (RS1) and intermediate RS (RS2) encapsulates the DSA-REQ message in its own DSA-REQ that is sent on the RS's primary CID to MR-BS. The encapsulated DSA-REQ message will eventually reach MR-BS.

MR-BS allocates a service CID A for the *SF*, and chooses a connection switch path (CSP) for it.. If such CSP does not exist, MR-BS will create a new CSP for it. The CSP may be identified by a Path-ID and reflect the CID mapping information, for example, on a relay path <RS1, RS2>, a CSP <B, C> for service connection A means the traffic on CID A shall be mapped onto CID B in RS1 and the traffic on CID B shall be mapped onto CID C in RS2.

MR-BS shall notify the corresponding RSs on the relay path of the CSP and corresponding action for the service CID A. The CSP path information and related action may be carried in the encapsulated DSA-REQ message initiated by MR-BS. In such case, 802.16 standard DSA-REQ message shall be extended. Optionally, MR-BS may use new defined Path Management messages to notify the CSP information and action. When MR-BS uses encapsulated DSx message to notify such information, after the 3-way handshake, the RSs on the relay path shall know how to forward MAC PDU, for example, for a CSP <CID B, CID C>,

MR-BS encapsulates the DSA-RSP message in order, and sends encapsulated DSA-RSP to RS2. The CSP path information is embedded in the DSA-RSP message.

RS2 shall de-capsulate the DSA-RSP and relay the de-capsulated DSA-RSP to RS1. RS2 may also update its CID forwarding table if the CSP path information is to be stored locally, RS1 shall de-capsulate the DSA-RSP and relay the standard DSA-RSP to MS telling it using CID A for service flow. RS1 shall update its CID forwarding table to use the CSP path information for CID A.

3 Text to be inserted into standard

----------Beginning of Text Changes----------

6.3.26 Connection Path Management

Relay path is defined as a series of consecutive relay links between MR-BS and the access RS. Traffic between a MS and MR-BS is forwarded along the relay path. Along the relay path, a MAC PDU on a connection CID A may be transparently relayed by RSs in its original form, or processed by RSs before relaying it. The RS's have to store and maintain forwarding tables which contain path and

forwarding information like the type of forwarding and the relations of incoming and outgoing CID's. The path and forwarding information is derived form MAC management messages which are send by the path management, from DSx MAC management messages or from MAC header/subheader information. Different forwarding mechanisms are defined.
The connection path management decides about the appropriate forwarding method and maintains a database which stores all relevant path and forwarding information. The connection path management is a functional entity which is inside the MMR. Connection path management in MMR includes connection path setup, connection path change and connection path delete which can be initiated by MR-BS, MS or RS, and triggered by service creation, service change, service deletion or MS/RS handover. MMR network could use DSx messages and 3-way handshake processes to mange connection path. The 802.16 standard DSx management messages shall be extended with relay path TLV and connection path TLV for the purpose. Optionally, MMR network could define new management messages and processes to mange connection path.

6.3.26.1 Transparent forwarding
In transparent forwarding, the MAC PDU header is not changed during forwarding on the RS. The CID keeps the same along the path between the logical communication endpoints. The path management assigns the CID and takes care of a unanimous assignment. Furthermore the assignment of the CID's and the binding to the local flow has to be done in a manner that the receiving end point can determine the originator of the MAC message.

6.3.26.2 Forwarding by CID mapping
In this mode the CID may change from hop to hop up to the final destination. The RS inserts the new CID value in the header and adapts further information fields in the header if necessary. The determination of the new CID and the type of forwarding action is done by a forwarding table lookup. As in transparent forwarding the assignment of the CID's and the binding to the local flow has to be done in a manner that the receiving end point can determine the originator of the MAC message.

6.3.26.3 Forwarding by tunneling
When MAC PDU is forwarded via tunneling, the CID may change hop by hop. Tunnels may be setup in flat or in stacked mode. In flat mode one additional header is prepend at the MAC PDU and is used for transport between the tunnel endpoints (access RS and MR-BS). In stack mode, when an access RS receives a MAC PDU from a MS, it leaves the header of the MAC PDU unchanged and prepends a new header. The same procedure is done on the next hops up to the MR-BS. In downlink direction the MR-BS prepends one or more header in front of the MAC SDU. The number of headers is given by the number of hops. The RS which receives such a MAC PDU removes the first header and forwards the MAC PDU. So the last hop receives a PDU in 802.16e style with only one header. The determination of the new CID and the type of forwarding action is done by a forwarding table lookup.

6.3.26.4 Forwarding by path subheader processing
In this mode the path between the communication endpoints is defined by the MAC PDU header and a subheader. The subheader contains a list of CID's. The CID in the MAC PDU header together with the CID's in the subheader defines the communication path. In downlink direction the MR-BS generates the MAC header with the CID of the connection to next hop and a subheader which contains a list of further CID which defines the connections to the further hops. The path information is given by the path management. The next hop which receives the message performs a CID wrap around. The wrap around is done by appending header CID at the end of the CID list in the subheader, remove first CID from list, set this as the new CID in header and update the header and

subheader IE's. The same procedure is done on the next hop. If the hop is a access RS, the RS removes the subheader after wrap around and sends a 802.16e compliant MAC PDU to the MS. The access RS may store the path information and reuse this information to generate a header/subheader for uplink communications. This may be feasible for connections which use the same CID's for downlink and uplink. In uplink direction, when an access RS receives a MAC PDU, it performs a lookup in its path database and generate the path containing subheader. Access RS updates the header, inserts the subheader and sends the MAC PDU to the next hop. If the next hop is an intermediate RS, it performs a CID wrap around which is opposite to the wrap around in downlink direction. IT prepends the CID from the header at the first position of the CID list, remove the last CID from the list, set this CID as the new CID in the header and update the header and subheader IE's.

Before path setup the path management selects an appropriate forwarding method according to the following constrains:

QoS constrains of the connection
Type of connection (data or management)
Available resources in MMR cell
Current topology of MMR cell

For data message, RS may transparently relay or do CID mapping on the MAC PDU when relaying it. The CID mapping here refers to the operations that a RS process a MAC PDU based on the CID(s) and IE(s) of the MAC PDU header/extended sub-header/sub-header, when relaying the MAC PDU. For example, swapping CID/stacking CID/popup CID/adding a CID list/removing a CID list/ in the MAC PDU header/extended sub-header/sub-header. When RS uses CID mapping on the MAC PDU, the MAC PDU may undergo a series of connections along the relay path. Connection path for a particular MAC PDU that is sent via CID C(0) on the access link is identified by a Path-ID and defined as the sequence of CIDs <C(1), C(2), …, C(n)>, where for 1<=i<=n, C(i) is the CID allocated to identify a transport connection between MR-BS and RS(i). When RS(i) transparently relays an ingress connection C(i), C(i) and outgress connection C(i+1) are same CID. Here ingress connection is the connection on which the MAC PDU is received, outgress connection is the connection on which the MAC PDU is transmitted. It is possible that some RSs on a connection path transparently relay ingress connection.

In MMR networks, as a RS may be allocated one or more transport connections, there may be several connection paths for a given relay path. These connection paths could be provided differentiated QoS. As connection path provide finer granularity than relay path, it helps better load balancing capability in a MMR network and QoS provision for a service flow.

RS shall use the connection path information to relay a connection. The connection path information could be retrieved from the CID forwarding table in the RS, or retrieved directly from the header/extended sub-header/sub-header of the received MAC PDU. In the former case, after a service connection C(0) is created for a service flow and a connection path <C(1), C(2), …, C(n)> is created for C(0), RS(i) (1<=i<=n) on the relay path shall be notified of corresponding CID mapping information. MMR could use extended DSx management messages or new management message for this purpose. The CID mapping information tells RS(i) to take what actions to relay ingress connection(s) to outgress connection(s). RS shall support translation (replace ingress CID with outgress CID), encapsulation (stack outgress CID), de-capsulation (popup ingress CID) and transparent relay action. Multiple ingress connections could be mapped onto one outgress

connections. One ingress connection could be mapped onto one or multiple outgress connections.
In the latter case, after a service connection C(0) is created for a service flow and a connection path <C(1), C(2), …, C(n)> is created for C(0), access RS on the relay path shall be notified to add connection path information to the header/extended sub-header/sub-header of the MAC PDU it sends to MR-BS or to retrieve header/extended sub-header/sub-header information of the MAC PDU it sends to MS. Intermediate RS could directly relay the received MAC PDU using the connection path information in the header/extended sub-header/sub-header. MMR could use extended DSx management messages or new management message for this purpose.
MR-BS shall also bind the connection path with the corresponding relay path. When a relay path is deleted or changed, the connection paths on the relay path shall be deleted or changed too.