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Title	Data forwarding and routing path setup for IEEE 802.16j multihop relay networks
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Re:	Submitted in response to Call for Technical Proposals for IEEE 802.16j issued on 2006-10-15
Abstract	This contribution describes a data forwarding solution for the IEEE 802.16j at MAC layer. We propose to use path CID to identify each routing path between BS and a RS. It not only reduces the routing table size significantly comparing to the method of forwarding data with SS CID, but also simplify the routing management work caused by the mobility of SS/RS nodes. We also propose to use forwarding CID to identify the next hop so that ambiguity may be eliminated. To setup the routing path for data forwarding, we also propose to use path creation and ACK message to create the routing path when centralized routing scheme is used.
Purpose	This contribution is about a data forwarding solution for the IEEE 802.16j multihop relay networks.
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Data forwarding and routing path setup for IEEE 802.16j multihop relay networks

1 Introduction

Comparing to the IEEE 802.16e network, the IEEE 802.16j network aims to provide broadband access with the help of relay station (RS) [1, 2]. It may forwards the data from BS/SS to SS/BS over one or more relay stations. It is known that in 802.16 network data communication between BS and SS in MAC layer is based on the connection ID (CID), which is used for resource allocation and determining the belonging of data.

With the including of RS in communication, the data packet may be forwarded over multiple hops. Thus, routing has to be considered at the MAC layer in the IEEE 802.16j standard. Routing covers many aspects such as routing state machine, path setup and maintenance, data forwarding, etc. In this proposal we focus on the data forwarding and routing path setup.

2 Problem of Data Forwarding with CID of SS.

As we have mentioned, CID is used in IEEE 802.16 [3] network for resource allocation and data identification at MAC layer. Thus, one of the methods for data forwarding is each RS maintain a routing table for all the CIDs that belong to the SSs that are either attached to itself or attached to its descendent RSs. Figure 1 shows an example of data forwarding with CID of SSs where xi (i=1,2,…,7) are CID of SSi (i=1,2,…,7).

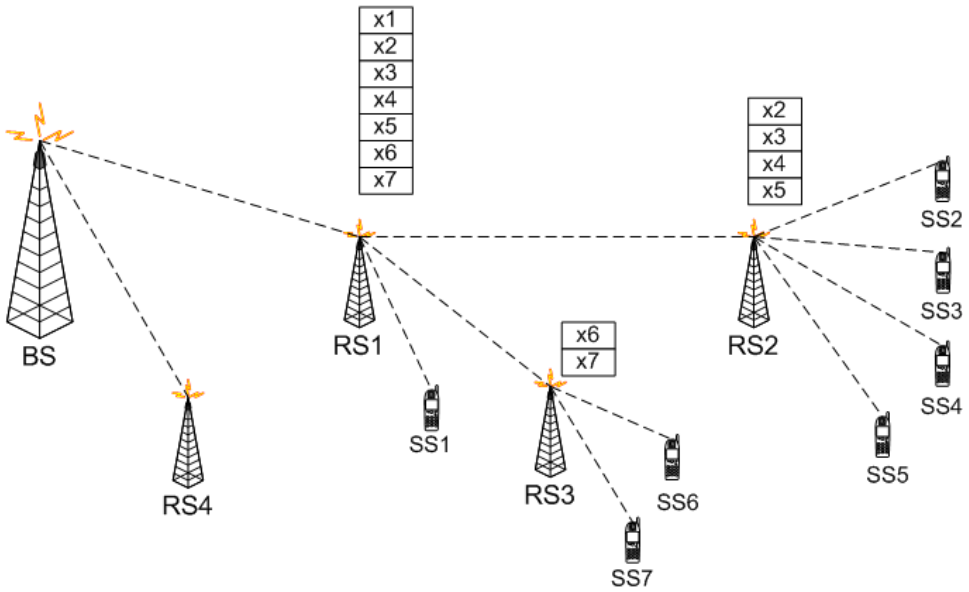

Fig. 1. Data Forwarding with CID of SSs.

With above method, there are some disadvantages of this method:

- The routing table size can be very large as each RS has to maintain a routing table that contains all the CIDs assigned to SSs of itself or SSs belong to its descendent RSs.
- When an SS move from one RS to another RS, then the system has to cancel all the routing entry of RSs that no longer on the path and then create routing entries at those RSs that are new in data forwarding for this SSs. For example, with scenario showed in Fig 1, if SS7 move from RS3 to RS4, the BS has to notify the RS1 and RS3 to remove routing entry of CID x7 first and then create a routing entry at RS4 for it.

3 Forwarding CID and Path CID

To reduce the routing table size and simplify the cost caused by the node mobility. We propose to assign each RS a data forwarding CID for next hop identification and path CID to identify a special path.

3.1 Forwarding CID

The forwarding CID is used to identify a RS. It is assigned when an RS enters the network belong to a BS and will not changed unless it leaves the cell of the current BS. The forwarding CID is used to identify next hop in data forwarding. When a RS receives a packet form BS/RS, it first checks whether the CID is equals to its forwarding CID; if not, then it drops the packet immediately. If the packet is from SS, then it searches in the SS CID table and determine whether it should forward it.

3.2 Path CID

A path CID identifies a path between the BS and a RS. A RS only have one forwarding CID but can have multiple path CIDs. Fig. 2. shows the concept of forwarding and path CID in which f0, f1, f2 and f3 are forwarding CID for BS, RS1, RS2 and RS3; p1, p2 and p3 are path CIDs for paths from BS to RS1, RS2 and RS3. Besides routing table, each RS also maintains a table of SS CID for those SSs that attach to it so that it can know whether a packet is from its SSs.

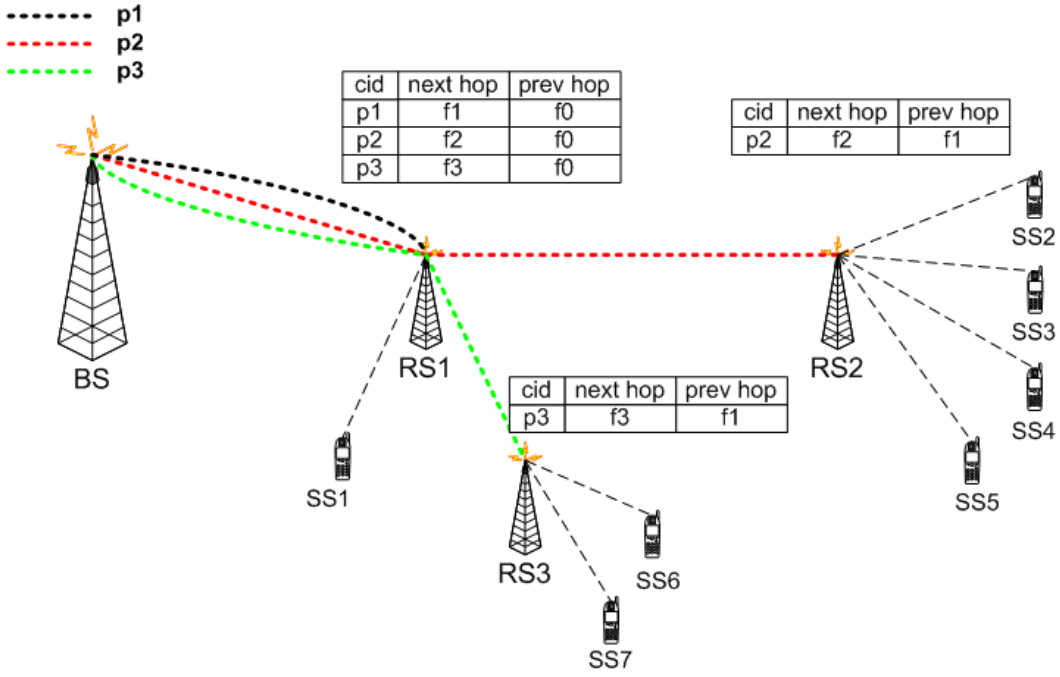

Fig. 2. Routing with Path CID

It is obvious that the routing table can shrink much with path CID. A RS only need to maintain the path CIDs of those RSs who depend on it and CIDs of SSs who directly attached to it. It increases the speed for packet processing.

There are several advantages of using path CID in forwarding packet:

- When SSs open/close sessions with new CIDs, there is no need to change the routing table on the intermediate RSs.
- When a SS switch to a new RS, only the routing table at RSs of last hop need be updated with those CIDs belong to this SS.
- When a mobile RS switch to a new RS, it only needs to update those affected RSs along the routing path with the path CIDs.

3.3 Packet Format for Data Forwarding

Fig.3. shows the packet format we proposed to forward data over multi-hop with forwarding and path CID. The forwarding CID is put in the generic MAC header while path CID is attached after it. The forwarding CID is updated hop by hop while path CID are not changed during the forwarding. The values for the headers are as follows:

- ***CID:*** data forwarding CID, i.e., the CID used for forwarding by the RS at the next hop.
- ***Type***: extended sub-header type, defined as RT_DATA_FORWARDING
- ***CID_0*:** path CID, i.e., the CID used to identify the path used by the RS in the data forwarding.
- ***P:*** priority level, 3 bits, to indicate the priority level of the message.
- ***TTL:*** 5 bits. Time to live field.

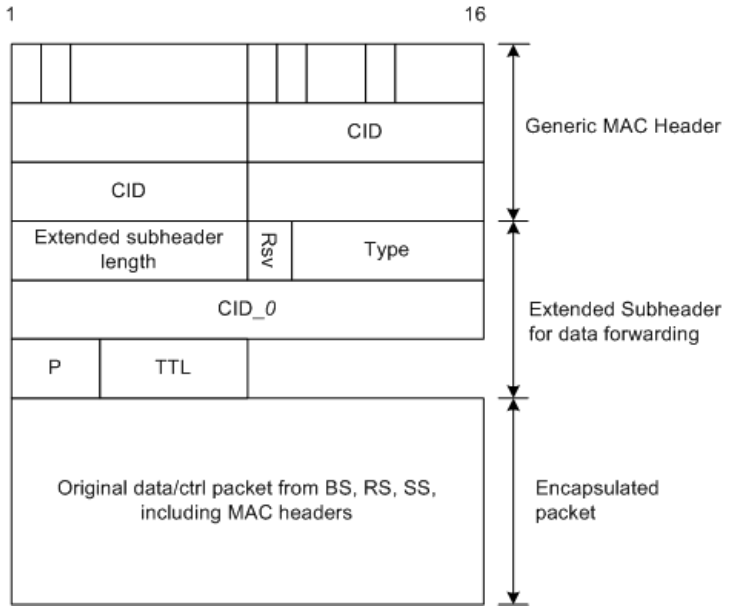

Fig.3. Data packet encapsulation header for data forwarding in medium access control layer

Fig.4. shows an example that how the forwarding CID and path CID are used for data forwarding, in which f1, f2, f3 are forwarding CID of RS1, RS2, and RS3. p1, p2 and p3 are path CID.

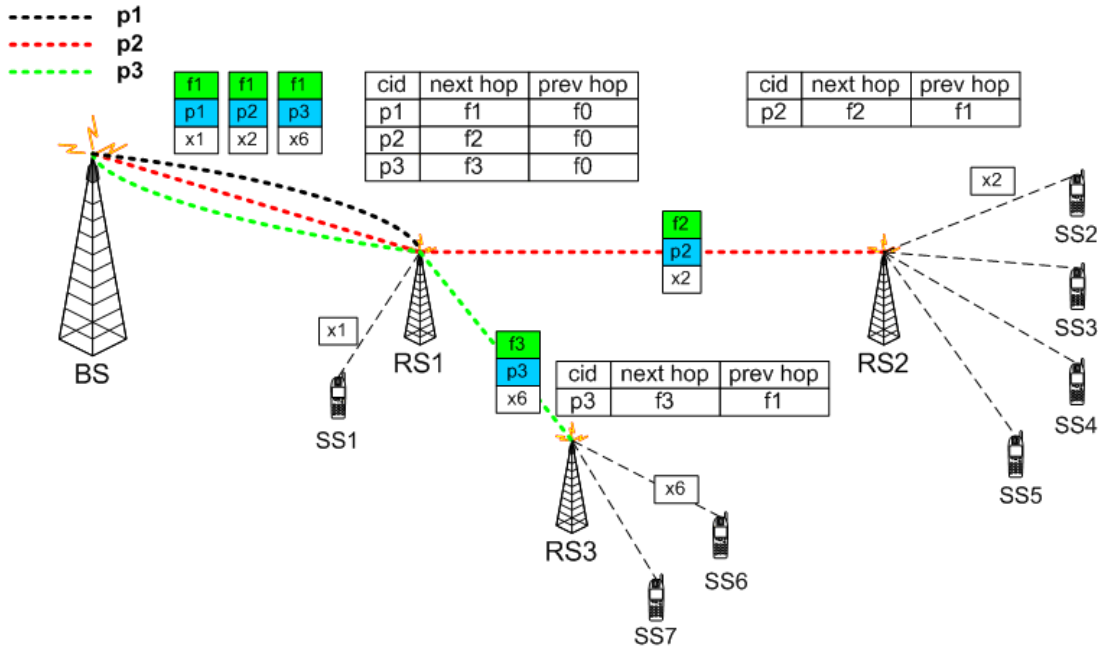

Fig.4. Data forwarding with forwarding and path CID

The reason why we use forwarding and path CID instead of path CID only is because we want to avoid ambiguous in interpreting the received packet at a RS. For example, assume the topology is like the one show in Fig 5, in which a broken links exists between RS1 and RS2 and it is not suitable for data forwarding. However, RS2 may be able to receive packet from RS1 occasionally. The routing path from BS to RS2 is via RS1 and RS3. However, during the communication, RS2 may receive data from both RS1 sometimes. With only path CID, it is hard for RS2 to differentiate it from the one from RS3. If it treats them as two different packets, then bandwidth may be wasted when the RS3 transmits both copies of packet to SSs.

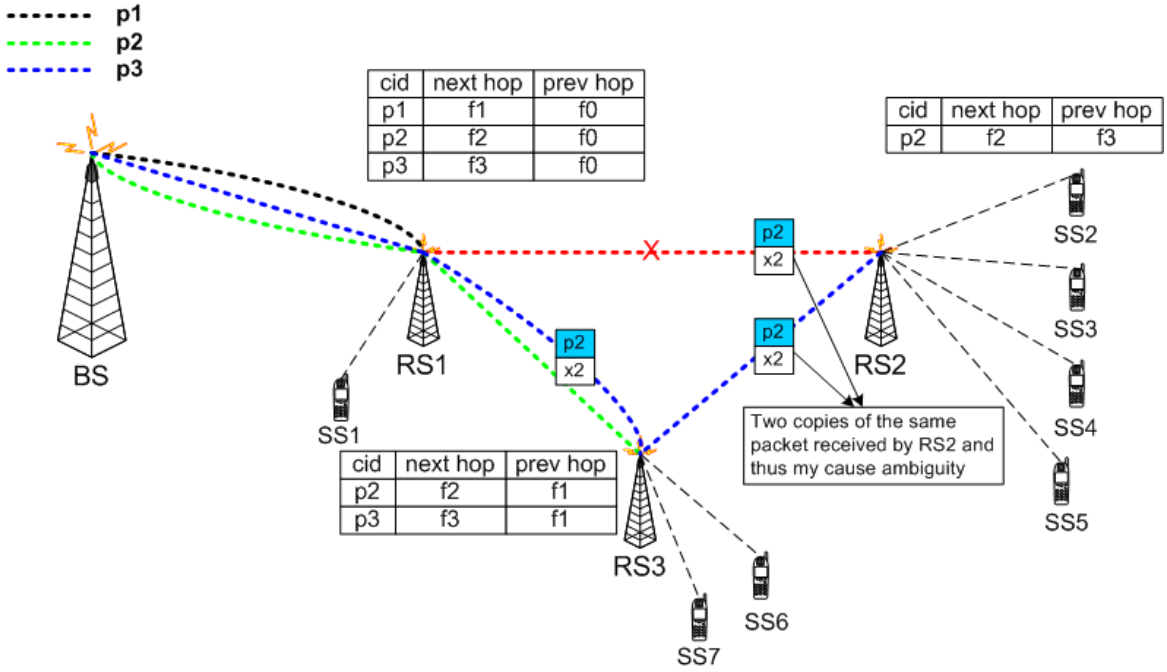

Fig.5. Path CID may cause ambiguous in packet processing

With forwarding CID, the ambiguity caused by the broken links can be avoided as showed in figure 6.

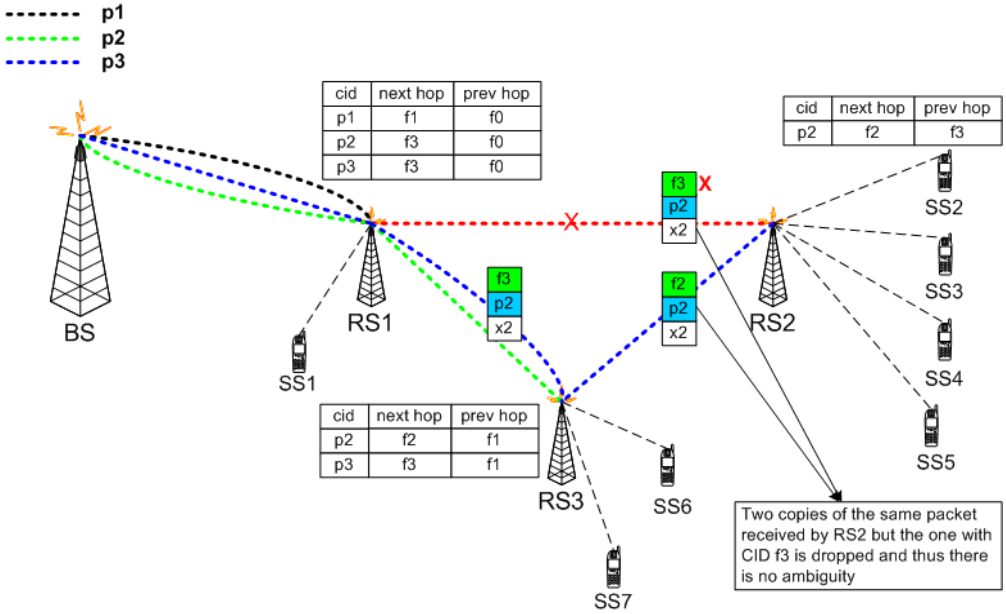

Fig.6. Forwarding CID avoids ambiguity

Another reason we use forwarding CID is to accelerate the packet processing at the RSs. A RS can determine whether it needs to process the packet from BS or others RS without look through the routing table based on the forwarding CID.

The forwarding CID may also simplify the routing management, for example, in routing path setup.

4 Routing Path Creation

In this section, we propose the control message for path setup with the proposed data forwarding method. We assume centralized routing scheme is used. BS chooses the routing bath based on the topology information and then send the path creation message to the RSs on the path. These RSs forward the message hop by hop until it reaches the last hop. As packet creation message maybe lost on the path, thus, the RS at the end of path should send back a path creation ACK to notify the BS that the path has been created successfully. The BS should resend the path creation message if the timer for path creation ACK is timeout. Once receive the ACK, it is safe for the BS to start scheduling data with the path. Fig. 7 shows the path creation process.

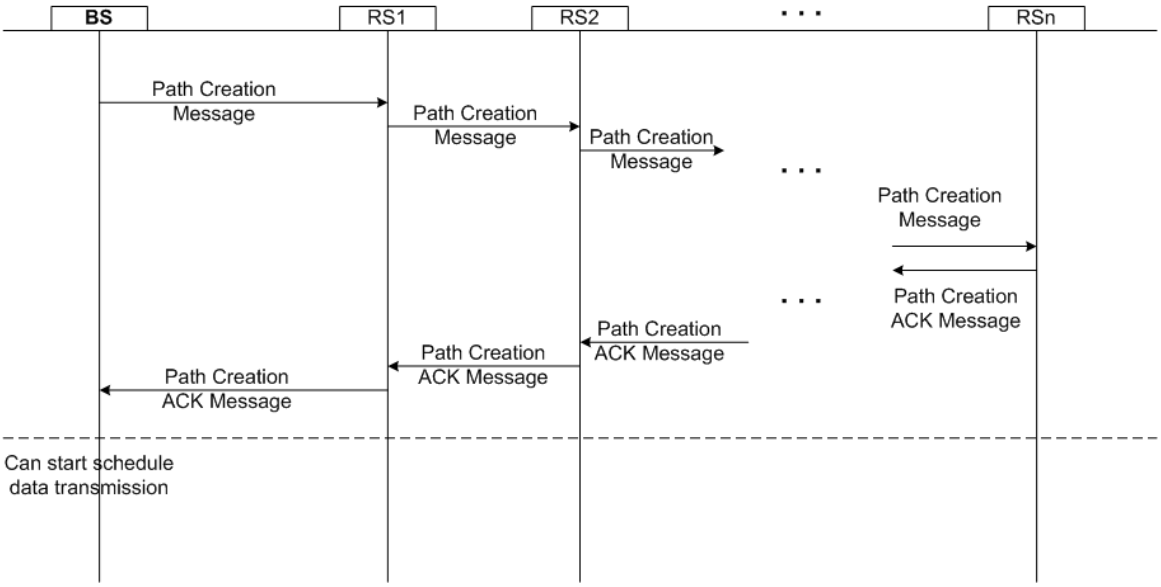

Fig.7. Path creation process

The path creation packet has the format as illustrated in Fig. 8.

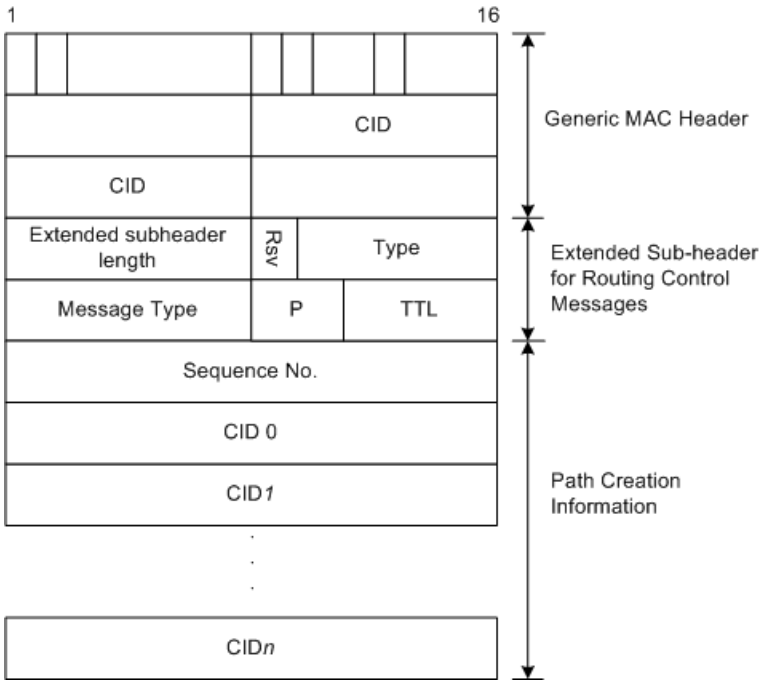

Fig.8. Path creation packet format

In Fig.8, the information contained in the packet is:

- ***CID*****:** the forwarding CID of RS in next hop. It is updated by each RS when forwarding to next hop based on the CID information contained in the packet.
- ***Type*****:** extended sub-header type for routing control message.
- ***Message Type:*** MESSAGE_RT_MAN_CENT_PATH_CREATION.
- ***P:*** priority level, 3 bits, to indicate the priority level of the message.
- ***TTL:*** 5 bits. Time to live field.
- **Sequence No**: the sequence number of this path.
- ***CID 0:*** the CID assigned to this path**.**
- ***CID 1 – n***: the forwarding CIDs of RSs involved in the routing. It is arranged in the order of hop count from low to high. Forwarding CID n is the last hop of the path. The intermediate router should add a routing entry with this ID as destination. An RS should record the previous and next hop of a given path.

The format of path creation ACK is illustrated in Fig. 9.

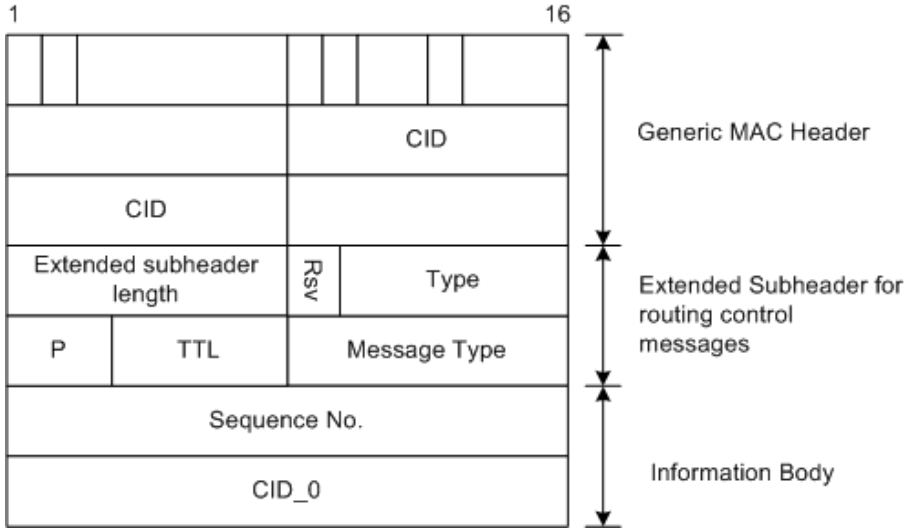

Fig.9. Path creation ACK packet format

The information of fields for the packet format illustrated in Fig. 7 is described as follows:

- ***CID:*** forwarding CID of next hop. Refer to Section 4 for the proposed forwarding CID and path CID.
- ***Type:*** extended sub-header type for routing control message..
- ***Message Type:*** MESSAGE_RT_MAN_CENT_PATH_CREATION_ACK.
- ***P:*** priority level, 3 bits, to indicate the priority level of the message.
- ***TTL:*** 5 bits. Time to live field.
- ***Sequence No***: sequence number for the routing control message.
- ***CID_0***: the path CID of the RS for which this path is created. Refer to Section 4 for the proposed forwarding CID and path CID.

5 Summary

In this proposal, we have proposed a data forwarding and path creation scheme for the 802.16j relay network. The method is efficient in data forwarding. It also avoids the ambiguity that may cause with path CID only data forwarding method. It also accelerates the data processing and simplifies the routing path management.

6. Text Proposal

---------- **BEGIN PROPOSED TEXT** ----------

[Modify the corresponding sections as follows:]

[Add the following subclause and text in terms definition and terminology section]
Relay Station Forwarding CID (Forwarding CID): A 16-bit value that identifies a relay station in data forwarding. Data packet sent from BS or other RS to this RS should contain this CID in the MAC header so that it knows the packet should be processed by itself.

Relay Path Connection Identification (Path CID): A 16-bit value that identifies a routing path between the BS and a RS. It is used for data forwarding on both directions.

[Add following subclause and text in: 6.3.2.2.7 Extended subheader format]
6.3.2.2.7.9 Data forwarding extended subheader

The format of data forwarding extended subheader is showed in table 13m:

Table 13m: Data forwarding extended subheader

Name	Size	Description
Path CID	16 bits	The path CID of the forwarded packets.
P	3 bits	Priority level
TTL	5 bits	Time-to-live field

6.3.2.2.7.10 Routing control message extended subheader

The format of routing control message extended subheader is showed in table 13n:

Table 13n: Routing Control Message subheader format.

Name	Size	Description
Message Type	8 bits	The types of the message:
P	3 bits	Priority level
TTL	5 bits	Time-to-live field

[Modify the follow text in 6.3.2.2.7 Extended subheader format]

Table 13b: Description of extended subheaders types (DL)

ES Type	Name	ES body size	Description
0	SDU_SN extended subheader	1 byte	See 6.3.2.2.7.1
1	DL Sleep control extended subheader	3 bytes	See 6.3.2.2.7.2
2	Feedback request extended subheader	3 bytes	See 6.3.2.2.7.3
3	SN request extended subheader	1 byte	See 6.3.2.2.7.4
4	PDU SN(short) extended subheader	1 byte	See 6.3.2.2.7.7
5	PDU SN(long) extended subheader	2 bytes	See 6.3.2.2.7.8

6	Relay data forwarding extended subheader	2 bytes	See 6.3.2.2.7.9
7	Relay routing control message extended subheader	1 byte	See 6.3.2.2.7.10
8-127	Reserved	---	---

Table 13c: Description of extended subheaders types (UL)

ES Type	Name	ES body size	Description
0	MIMO mode feedback extended subheader	1 byte	See 6.3.2.2.7.4
1	UL tx Power Report extended subheader	1 byte	See 6.3.2.2.7.5
2	Mini-Feedback extended subheader	2 bytes	See 6.3.2.2.7.6
3	PDU SN(short) extended subheader	1 byte	See 6.3.2.2.7.8
4	PDU SN(short) extended subheader	2 bytes	See 6.3.2.2.7.8
5	Relay data forwarding extended subheader	2 bytes	See 6.3.2.2.7.9
6	Relay routing control message extended subheader	1 byte	See 6.3.2.2.7.10
7-127	Reserved	---	---

[Add following subclause and text in: 6.3.25 Relay path management and routing]

Add the subclause as indicated:

6.3.25.1 Forwarding CID

Each relay station should be assigned a forwarding CID. The forwarding CID should be assigned in the RNG-RSP and REG-RSP messages. It should be used in data forwarding and path management such as path creation and maintenance. The forwarding CID is allocated in a predefined region as specified in Table 345.

6.3.25.2 Path CID

For each path created between BS and RS, a unique path CID should be assigned and notifies all the RSs that involved in the path of this CID and the relative next hops on both directions. The path CID is used for data forwarding on both directions between a RS and BS. The path CID is assigned from the CID region defined for Transport CIDs, Secondary CIDs and Path CIDs.

6.3.25.3 Path Creation

A path creation message should be sent by BS to create a routing path when centralized routing scheme is used. The target RS should send an acknowledgement message along the path to notify the BS that the path has been created successfully. Once received the acknowledgement message, the BS can start to scheduled data transmission for this RS on the created path. A routing control message extended subheader *(defined in 6.3.2.2.7.10)* is used when send a routing control message such as path creation and path creation ACK.

Table xxx: Routing Control Message Type.

Message Type	Value
Path creation	0
Path Creation ACK	1
Reserved	0-255

6.3.25.4 Data Forwarding

When a data packet needs to be sent over multiple hops, a forwarding header, which consist of a generic MAC header plus a data forwarding sub-header(*defined in 6.3.2.2.7.9*), should be used to encapsulate the data packet when relaying is necessary. The CID field of the generic MAC header contains the next hop forwarding CID and the path CID is contained in the data forwarding sub-header. A RS determines whether it should process a forwarded data packet received from BS or other RS based on the forwarding CID. It determines the next hop of packet based on the path CID. The original data packet follows the data forwarding header.

[Modify the follow text in 10.4 Well-known address and identifiers]

Change Table 345—CIDs as indicated:

CID	Value	Description
Initial ranging CID	0x0000	Used by SS and MR-BS during initial ranging process
Basic CIDs	0x0001 – m	The same value is assign to both the DL and UL connection.
Primary management CIDs	m+1 – 2m	The same value is assign to both the DL and UL connection.
Forwarding CIDs	2m+1 – 3m	Used by MR-BRS/RS to address next hop in data forwarding and routing management.
Transport CIDs, Secondary Mgt and path CIDs	3m+1 – 0xFE9F	For the secondary management connection or routing path between MR-BS and RS, The same value is assign to both the DL and UL connection.
Multicast CIDs	0xFEA0 – 0xFEFE	A BS supporting AAS shall use this CID when allocating an Initial Ranging period for AAS devices.
AAS initial ranging CID	0xFEFF	A BS supporting AAS shall use this CID when allocating Initial Ranging period for AAS devices.
Multicast polling CIDs	0xFF00 – 0xFFF9	An SS may be included in one or more multicast polling groups for the purposes of obtaining bandwidth via polling. These connections have no associated service flow.
Normal mode multicast CID	0xFFFB	Used in DL-MAP to denote bursts for transmission of DL broadcast information to Normal model MS.
Sleep mode multicast CID	0xFFFB	Used in DL-MAP to denote bursts for transmission of DL broadcast information to Sleep mode MS. May also be used in MOB_TRF-IND messages.
Idle model multicast CID	0xFFFC	Used in DL-MAP to denote bursts for transmission of DL broadcast information to Sleep mode MS. May also be used in MOB_PAG-ADV messages.
Fragmentable Broadcast CID	0xFFFD	Used by the BS for transmission of management broadcast information with fragmentation. The fragment sub header shall use 11-bit long FSN on this connection.

Padding CID	0xFFFE	Used for transmission of padding information by SS and BS.
Broadcast CID	0xFFFF	Used for broadcast information that is transmitted on a downlink to all SSs.

---------- END PROPOSED TEXT ----------

References:

[1] "MMR Harmonized Contribution on 802.16j (Mobile Multihop Relay) Usage Models", *Document No. IEEE 802.16j-06/015*, 05 September 2006.

[2] "P802.16j - Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Multihop Relay Specification", March 2006.

[3] "Part 16: Air Interface for Fixed Broadband Wireless Access Systems", *IEEE Std 802.16-2004*, October 2004.