Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Connection Identification and Transmission for Relay Support**
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Re:	IEEE 802.16j-06/027: "Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	This contribution proposes a connection identification and a relay transmission schemes for IEEE 802.16j
Purpose	Proposes a connection identification and a relay transmission schemes for IEEE 802.16j
Notice	
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Connection Identification and Transmission for Relay Support

1. Introduction

In the IEEE 802.16e system, SS connections are identified by SS CIDs which are carried by an MAP-IE in DL-MAP and UL-MAP in the access links. However, there will be some problems if the legacy connection identification scheme is directly applied to the IEEE 802.16j Multi-hop Relay system. This contribution introduces three kinds of possible connection identification schemes and the corresponding arrangements on relay transmission, and the text proposal will propose the most efficient scheme based on the numerical analysis and comparison.

The rest of this contribution is organized as follows: The possible connection identification and transmission schemes are introduced and compared in Section 2, and the most efficient scheme will be included in the text proposal in Section 3. Finally, the numerical comparison and analysis are given in Appendix.

2. Possible Connection Identification and Transmission Schemes

There are two kinds of methods for connection relaying over relay links, which are without or with the specific relay identifications. For the previous method, a connection could only be identified and transmitted in accordance with the SS's identification. For the latter method, a connection could be identified and transmitted by two possible types of identification: one is per hop relay link identification and the other is end-to-end relay path identification. By distinguishing from different types of identifications, a connection can be transmitted in three possible relaying schemes, which are (1) SS oriented relaying scheme, (2) relay link oriented relaying scheme, and (3) relay path oriented relaying scheme. We will briefly discuss and compare these schemes in this section

(1) SS oriented relaying scheme

In this scheme, all relay links are not assigned with the identifications whereas the connection over relay links is identified by SS CID the same as for access link. Upon receiving a burst from superordinate station, RS performs decode-and-forward and identify which bursts shall relay to subordinate RS, or forward to destination SS, or omitted. In order to complete this kind of work, RS shall records all the CID of descendent SSs into CID table. The size of such CID table in each RS is the direct proportion of the number of subordinate SSs, and MR-BS grants the resources of the relay links and the access link per SS. As illustrated in figure 1, three CIDs are used for transmission in relay and access link when three SSs are served by RS2. MR-BS shall grant three parts of resources for these three SSs, and construct three MAP-IEs with three CIDs in the MAP to indicate the RSs about the transmission in relay links. RSs along the relay path are in charge of identifying bursts by looking up their CID table and forwarding bursts toward SSs.

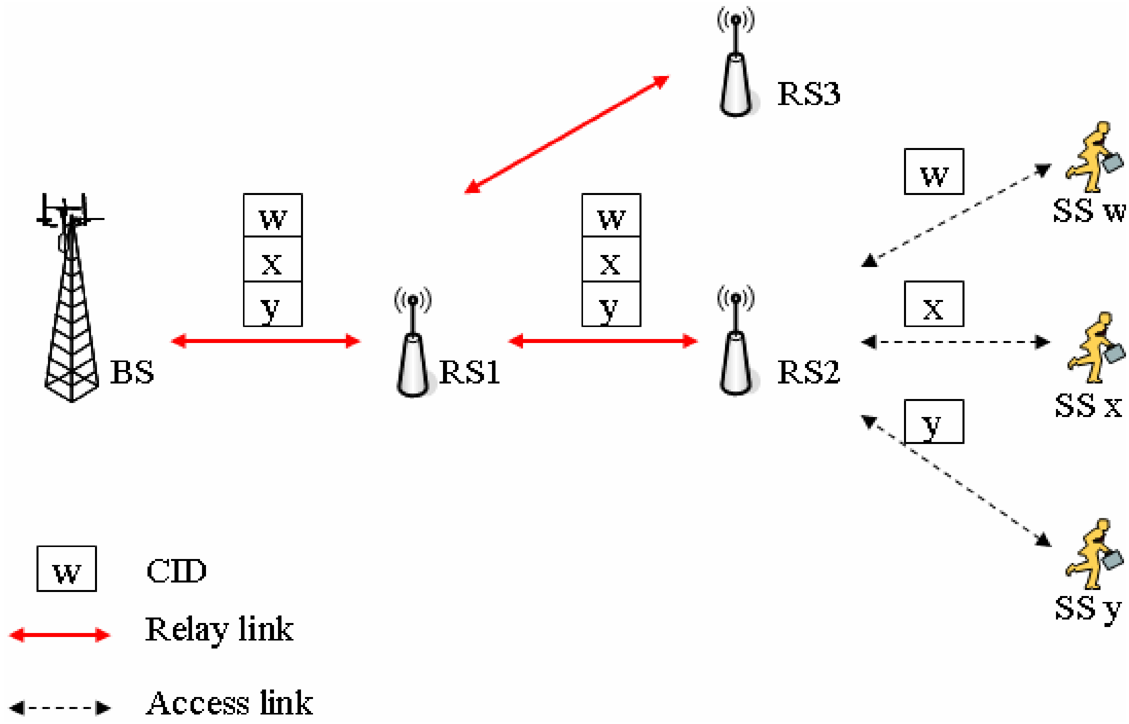

Figure 1. SS oriented identification and transmission

(2) Relay link oriented relaying scheme

In this scheme, each RS is assigned with a specific CID for the relay link between itself and its superordinate station so that each connection in relay links and access link is no longer identified by the same CID. In access link, connections are identified by SS CID while connections are identified by relay link CIDs in relay links. During a RS startup and/or establishing a relay link with associated MR-BS or RS, the associated MR-BS shall assign a CID for this relay link. When forwarding, RS processes the received bursts and marshals the bursts into another relay burst for each direct relay link by identifying the destination. Because of distinguishing between various received bursts for further forwarding, RS shall record the mappings between direct relay links and the descendent SSs, and update the CID table when each descendent SS leaves or enters the network. The size of the CID table in each RS is the direct proportion of the number of the direct link subordinates RSs plus all descendent SSs, and MR-BS grants resource per relay links and per SS. As showed in figure 2, although there are only three CIDs used for three relay links and three CIDs used for access links, MR-BS have to grants three parts of resources for relay links and three parts of resources for access links. Thereafter, MR-BS shall indicate RSs about the relay burst conveying in accordance with the relay link CID, as well as indicate SS about the access burst accessed in accordance with the SS CID. That is to say, for a relay burst, each RS along the relay path only needs to forward the burst to the direct link subordinate RSs or destination SS by referring to the relay link CID or SS CID. However, the disadvantages of this scheme are that each burst must be processed by intermediate RS in two purposes: one is to distinguish the destination SS of this burst whether belonging to this RS, another is to find out the next-hop relay link CID of this burst for CID translation.

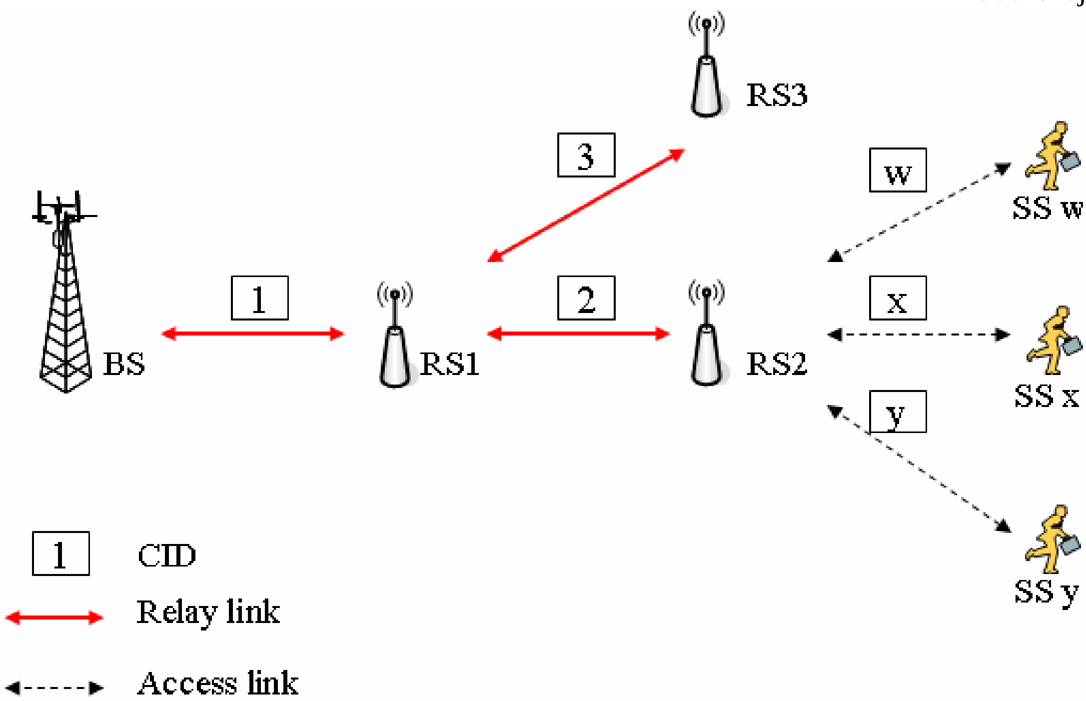

Figure 2. Relay link oriented identification and transmission

(3) Relay path oriented relaying scheme

In this scheme, each RS is assigned with a CID for the relay path, which consists of one or more relay links, between BS and itself. By this way, MR-BS can transmit data bursts to an SS in two steps: first step is to forward data bursts to the destination RS by a specific relay path CID, and the second step is that the destination RS transmits data bursts to the SS by a specific access link CID. When a RS startup and/or establishing a relay link with associated MR-BS or RS, MR-BS shall update network topology, establish a relay path destined to the RS, and assign a specific CID for the relay path. Once a SS enters or leaves the network, the intermediate RSs along the relay path needs not being informed of this event. Only the destination RS will be indicated that of the CID table updating for the SS. Hence, the size of the CID table in each RS is the direct proportion of the number of subordinate relay paths plus all served SSs and MR-BS grants resource per relay paths and per SSs. Figure 3 depicts the concept of this scheme. One relay path is constructed between MR-BS and RS 2, and only one CID is used to convey relay burst from MR-BS to RS2. MR-BS has to grants two parts of resource: one for the relay path and one for access links. Then MR-BS shall notify RSs about the relay burst conveying in accordance with the relay path CID, as well as indicate SS about the access burst accessed in accordance with the SS CID. That is to say, for each relay burst, intermediate RSs along the relay path only need to forward the burst to subordinate RSs by referring to the relay path CIDs. In this scheme, intermediate RS do not need to know the content of relay bursts. Only the destination RS shall deal with the bursts and transmit them to SSs. CID is not required to change during the transmission in relay path so that CID translation is not needed.

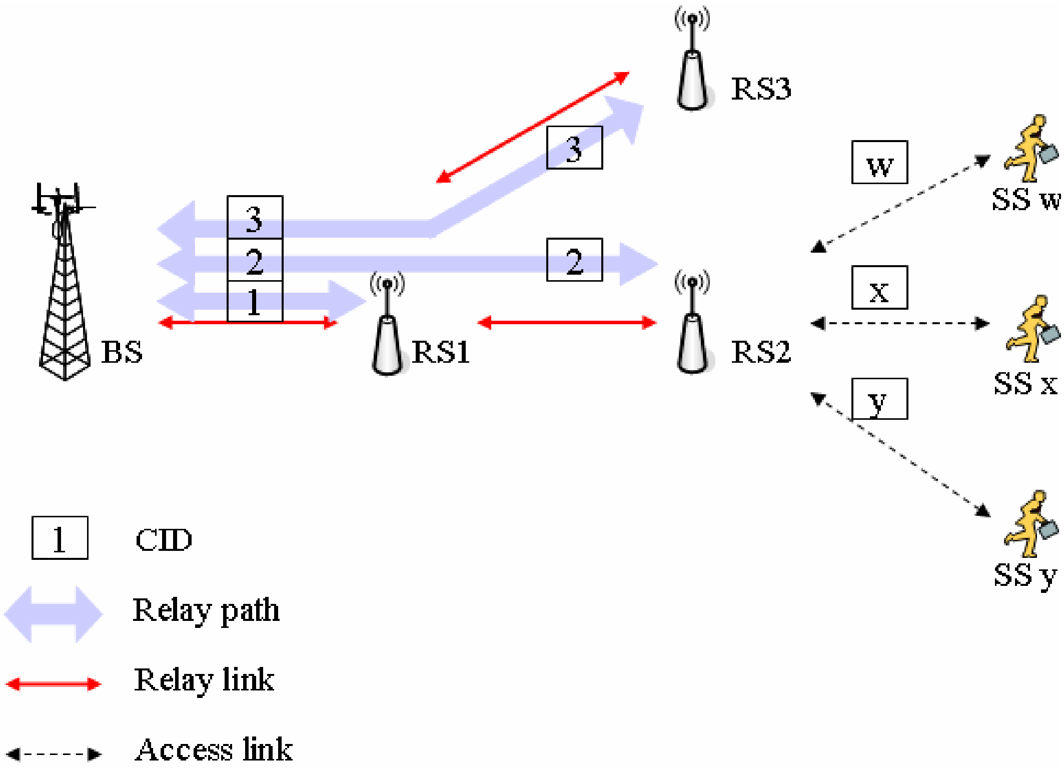

Figure 3. Relay path oriented identification and transmission

3. Proposed Solution

Based on the relay path oriented relaying scheme, this contribution proposes a new relaying scheme for 802.16 Task Group j. In the proposed scheme, each RS maintains a relay path for communicating with MR-BS and possible some access links for its served SSs. Each relay path is allocated a CID the same as the CID allocated for the RS at the end of this relay path (i.e., the destination RS), and all the data destined to that RS is transmitted with the CID. Upon receiving the relay burst from MR-BS, each direct link subordinate RS, e.g. RS1 or RS 2 identifies the burst by CID, and decide whether the burst needs to be forwarded to the next RS. The relay burst is forwarded in the same way for each intermediate RS until it is received by the destination RS. At that time, the destination RS shall decode the relay burst into the access burst and further transmitted to the destination SSs. As shown in Figure 4, MR-BS constructs a relay path with RS 3 and allocates CID 3 for this relay path. Thereafter, all the bursts destined to RS 3 is combined and transmitted with CID 3 along the relay path.

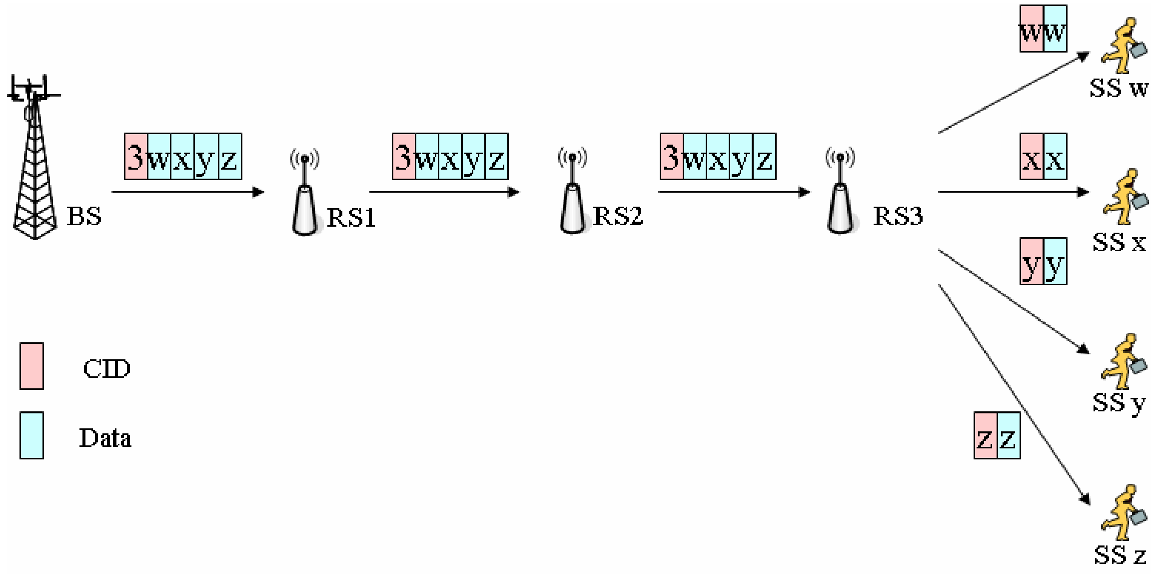

Figure 4. proposed relay path oriented relaying scheme

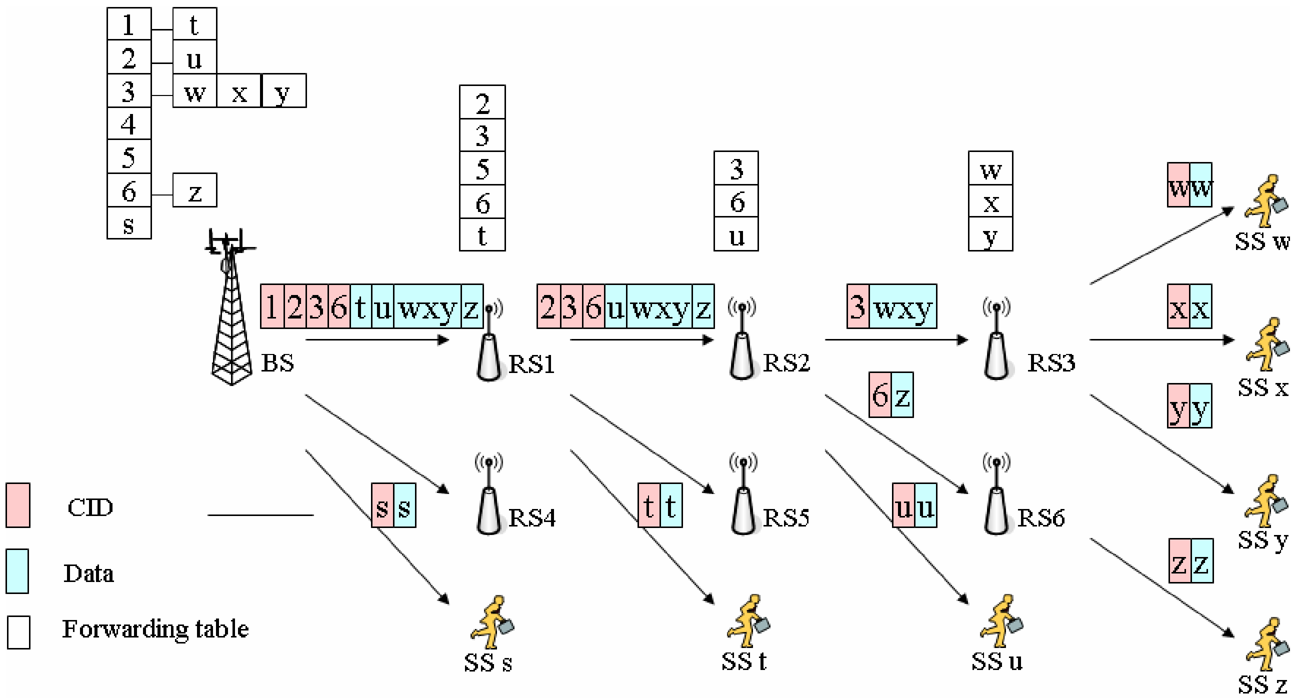

Figure 5. Overview of proposed relay path oriented relaying scheme

Figure 5 illustrates the overview of proposed scheme. As mentioned above, each RS shall maintains a relay path with MR-BS and allocated a specific CID. Each station in the cell shall know the direct link subordinate RSs and SSs for relaying. We assume a forwarding CID table is constructed by each station, including MR-BS and RSs. In this example, MR-BS transmits an access burst and relay bursts in the frame. The access burst is indicated by SS CID, s, while relay bursts is identified by relay path CID, 1,2,3,6. Upon receiving the bursts of SS t, u , w, x, and y, with relay path CID, 1, 2, 3, 6, RS 1 shall check the allocated CIDs in CID table to see if there are any relay burst for it. If RS 1 finds its relay CID allocated in the MAP, it stores the indicated bursts for access link forwarding. For other relay bursts, RS 1 would identify the CID and decide for further relaying or ignoring. The similar operations are done in RS2, where the relay and access bursts would be separated and forwarded to subordinate RS and SSs. Upon receives the relay burst in a frame, the destination RS of a relay path, e.g. RS1, RS2, RS3, or RS6, decodes the relay burst into access bursts and transmit these access bursts to the destination SSs with SS CID and indicated parameters from MR-BS. Note that the same process can be also applied for uplink case.

4. Summary and Text Proposal

4.1 Summary

This contribution compares three different schemes of connection identification and transmission schemes for IEEE 802.16j based on the numerical and logistical analysis. The SS oriented scheme will enforce RSs to make redundant processing in relay links, and the relay link orient and relay path oriented schemes can reduce the process overheads. By comparing with relay path oriented relaying scheme, relay links oriented relaying scheme needs to decode each data burst and translate CID for next hop relay. In order to prevent heavy processing power for the RS and reduce the overhead, we would like to propose a new relay path oriented relaying scheme including the following attributes.

- A relay path is associated with one or multiple relay links, and is allocated a CID for destination RS by MR-BS.
- For relay services, MR-BS grants resource based on the relay paths.
- Relay bursts are identified by the relay path CID in the relay links, while access bursts are identified by SS CID in the access links.
- Intermediate RS of a relay path identifies the relay bursts by the relay path CID and transmits them to subordinate RS if needed.
- Destination RS of a relay path is responsible for translating the relay burst into the access bursts and forwards the access bursts to the destination SSs.
- BS uses the relay path CID to manage RS.

4.2 Proposed text

--Start of the Text---

[Modify the corresponding sections as follows:]

[Add the following subclause and text in terms definition and terminology section]

relay path connection: a unidirectional mapping between base station (BS) and relay station (RS) medium access control (MAC) peers for the purpose of transporting relay service traffic. Relay path connection is identification by relay path connection identification (Relay CID). All SS traffic within the RS is carried on a relay path connection. *See also:* **relay path connection identifier**

relay path connection identification (Relay CID): A 16 bit value that identifies a relay path connection to equivalent peers in the MAC of the base station (BS) and relay station (RS). It maps to a relay service, which includes the services flows associated with the subscribe stations (SS) that served by the RS.

[Add the following subclause and text in 6.3.1.3 Addressing and connection for relay support]

Add the subclause as indicated:

Each air interface in RS could also have 48-bit universal MAC address, as defined in IEEE STD 802-2001. This address uniquely defines the air interface of the RS. It is used during the initial ranging process to establish the appropriate connections for RS. It is also used as part of the authentication process by which the MR-BS and RS can verify the identify of each other.

Relay connections are identified by 16 bit relay CID. At RS initialization, two pairs of relay connections (uplink and downlink) shall be established between the MR-BS and the RS. The two pairs of relay connections reflect the fact that there are only one relay traffic between an RS and the MR-BS for each direction. The relay connection is used by MR-BS and RS to exchange the control and data traffic of the RS and the SSs served by the RS.

The CIDs for the relay connections shall be assigned in the RNG-RSP and REG-RSP messages. The message dialogs provides two CID values. The same CID value is assigned to both members (uplink and downlink) of each relay connection pair.

For bearer services in relay connections, the setup and registration is identical to 6.3.1.1. When admitted or active, the service flows are uniquely associated with the combination of relay connections and transport connections. For relay services of the RS, all the bearer or data services shall be transferred in a relay connection from MR-BS to the RS.

[Modify the following subclause and text in 6.3.20.1 Types of data delivery services]

Change Table 132a as indicated:

Table 132a – Type of data delivery services

Type	Symbolic name of service type	Meaning
…	…	…
5	RLY	Relay Service dedicated for RS. For DL and UL relay connections shall supported by all the service types defined above.

[Add the following subclause and text in 6.3.20.2 Data Delivery in Relay Links]

Add the subclause as indicated:

This type of services is to support all the application defined in previous sections. This data can be provided as joint consideration of parameters that transport connections required. MR-BS shall consider all the QoS requirements and allocate a large and combined resource in the frame for relaying all the transport connections of SSs within a RS. Upon receiving the relay burst, the RS shall check the relay CID if it needs to relay the data. If yes, the RS relay the burst without data processing for forwarding to its superordinate RS or MR-BS in uplink case, and to subordinate RS in downlink case. Once the RS receives the burst that is destined to it, it shall process the data burst and transmit it to served SS. The following figures are the process for relaying service in MR-BS and each RS.

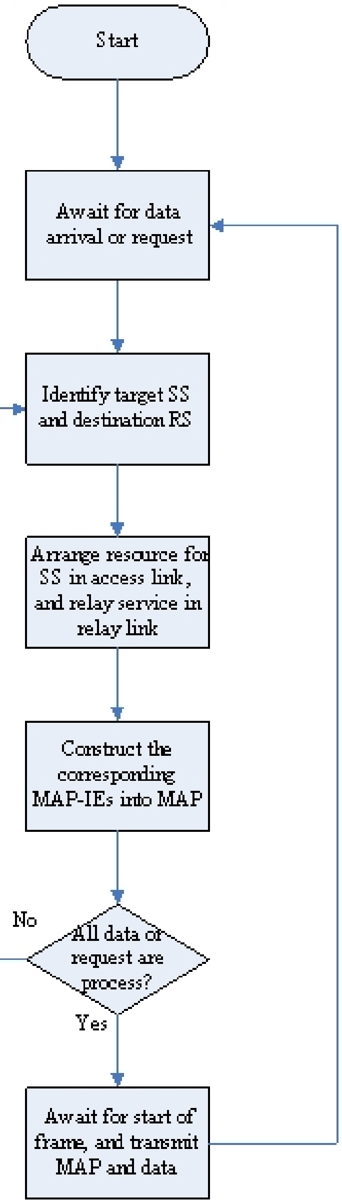

Figure xxx – Relay Service Flow Chart of MR-BS

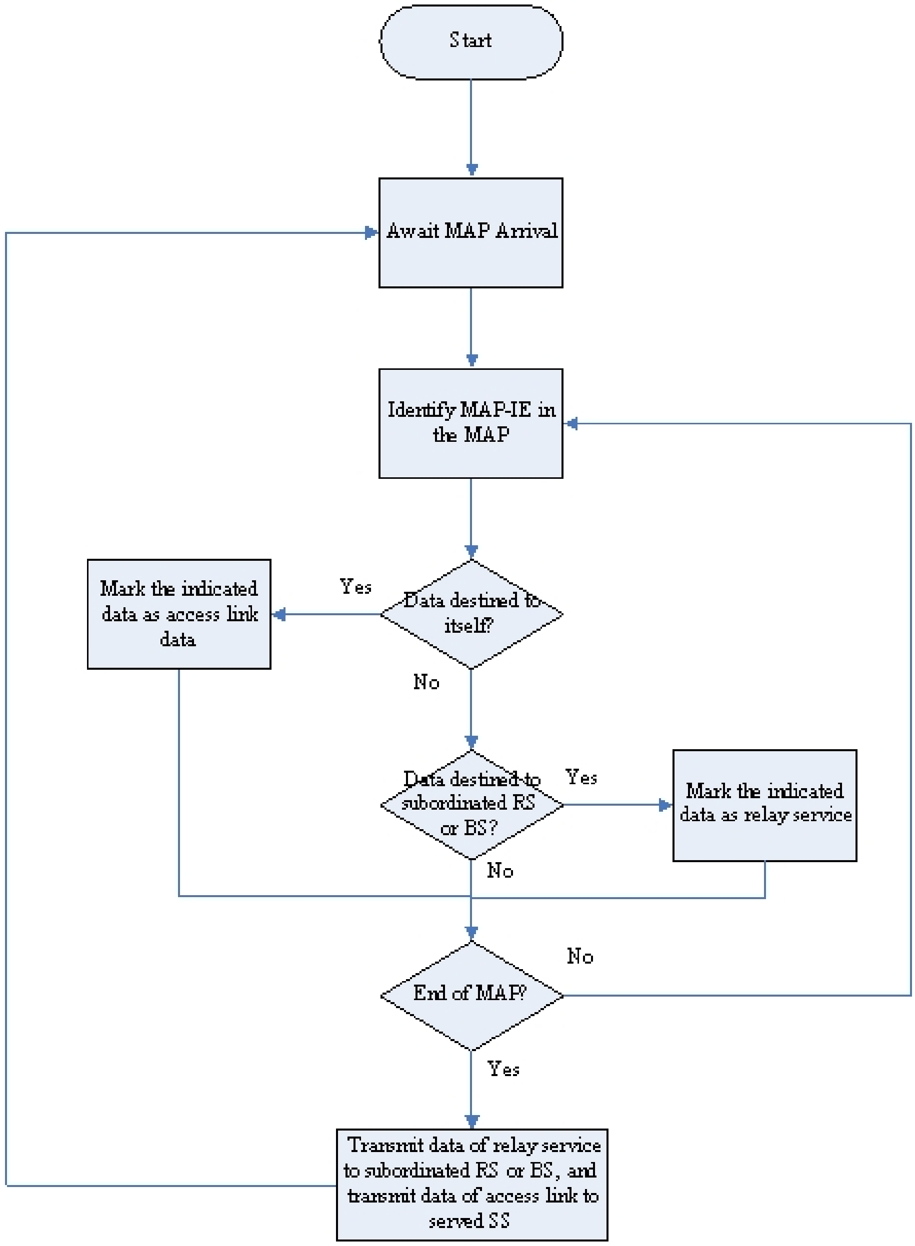

Figure xxx – Relay Service Flow Chart of RS

[Add the following text in8.4.5.3 DL-MAP IE format]

Change the following text in 8.4.5.3 as indicated:

Connection Identifier (CID)

Represents the assignment of the IE to a broadcast, multicast, or unicast address for access link, or to a relay service for relay links.

Note: the CID used in relay links indicates the destination RS, not intermediate RS along the relay path. CID for access link shall be carried in data until the burst is received by destination RS.

[Add the following text in8.4.5.4 UL-MAP IE format]

Change the following text in 8.4.5.3

CID

Represents the SS or RS to which the IE is assigned.

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

Change Table 345—CIDs as indicated:

CID	value	Description
Initial ranging	0x0000	Used by SS and MR-BS during initial ranging process
Basic CID	0x0001 – m	The same value is assign to both the DL and UL connection
Primary management	m+1 – 2m	The same value is assign to both the DL and UL connection
Relay CID	2m+1 – 2m+n	Used by RS and MR-BS for RS management, and downlink or uplink relay. The same value is assigned to both the DL and UL connections
Transport CIDs and Secondary Mgt CIDs	2m+n+1 – 0xFE9F	For the secondary management connection, the same value is assign to both the DL and UL connection.
Multicast CIDs	0xFEA0 – 0xFEFE	A BS supporting AAS shall use this CIS when allocating an AAS Ranging period (using AAS Ranging Allocation IE)
AAS initial ranging CID	0xFEFF	A MR-BS supporting AAS shall use this CID when allocating a 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	0xFFFFA	Used in DL-MAP to denote bursts for transmission of DL broadcast information to normal mode 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 mode multicast CID	0xFFFC	Used in DL-MAP to denote bursts for transmission of DL broadcast information to Idle mode MS. May also be used in MOB_PAG-ADV messages.
Fragmentable Broad-cast 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 MR-BS
Broadcast CID	0xFFFF	Used for broadcast information that is transmitted on a downlink to all SS.

--End of the Text---

5. References

[1] IEEE 802.16j-06/014r1, “Harmonized definitions and terminology for 802.16j Mobile Multihop Relay”

[2] IEEE 802.16j-06/015, “Harmonized Contribution on 802.16j (Mobile Multihop Relay) Usage Models,”

[3] IEEE 802.16-06/016r1, “Technical Requirements Guideline for IEEE 802.16 Relay TG,”

[4] IEEE 802.16-06/017r2, “Table of Contents of Task Group Working Document of Task Group Working Document,”

[5] IEEE 802.16-2004 specification

[6] IEEE 802.16e-2005 specification

[7] IEEE C802.16mmr-05_029r2, “Modification for Enabling RS Operations”

Appendix: Comparison and Analysis

To compare the overheads of the link relaying schemes mentioned above, we use the network topology shown in figure 6 to evaluate the performance by the above two criteria. The illustrated network topology is a tree structure graph with descendant degree 1 or 3 for relay link only. The degree here means the number of relay links directly connected by the station. Figure 6-1 and Figure 6-2 show the example of two-hop relay network while Figure 6-3 shows the example of three-hop relay network. We assume that the numbers of SS in each RS are the same and compare the criteria above in three cases below:

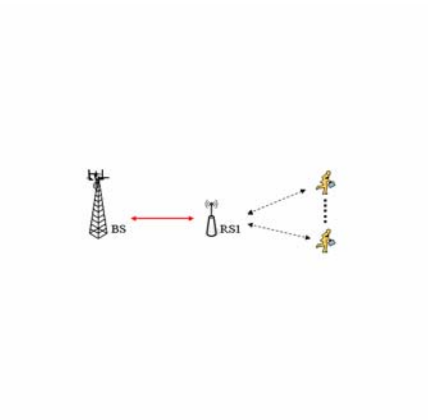

Figure 6-1: two-hop relay network (degree 1)

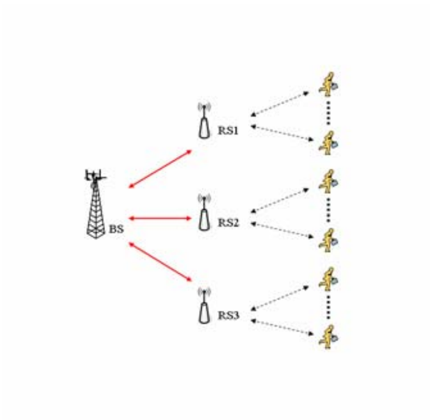

Figure 6-2: two-hop relay network (degree 3)

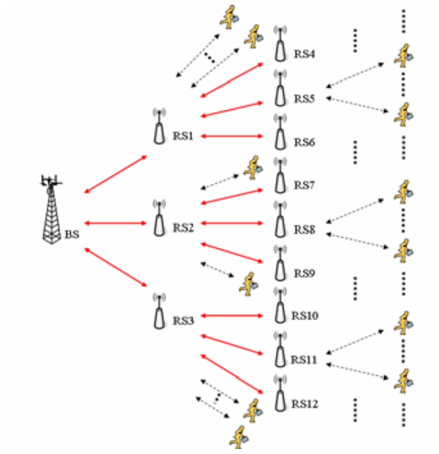

Figure 6-3: three-hop relay network (degree 3)

We analysis (1) SS oriented relaying scheme, (2) relay link oriented relaying scheme, and (3) relay path oriented relaying schemes by the following criteria:

- Processed CIDs in MAP:

  RS shall process CIDs in the MAP sent from MR-BS or superordinate RS to identify the data for further forwarding. Most data burst shall transmitted through RSs in first-hop, so we analysis the processing overheads by counting the CIDs in the MAP. Note that we only analysis the processed CIDs for relay links. In short, this represents the CIDs processed by each RS in MAP.

  The evaluation equation for each scheme is:

  SS oriented relaying scheme_$CID_proc = (1+NO_{RS_behind})* NO_{SS}$

  Relay link oriented relaying scheme_$CID_proc = 1$

  Relay path oriented relaying scheme_$CID_proc = 1 + NO_{R\text{-}path_behind}$

  Where NO_{RS_behind} and $NO_{R\text{-}path\_behind}$ denote as the number of RSs and relay paths behind the RS respectively, and NO_{degree} denotes as the number of subordinate relay links of the RS. NO_{SS} denotes as the number of served SSs of the RS.

- CID entries in RS

  Each RS would maintain a CID table to identify the received data and see if it needs to relay the data to subordinate RS or destination SS. Large amount of CID entries would increase the maintenance cost and the RS complexity. In this section, we only discuss the CID entries for relay links. In short, this represents the CIDs that RS shall maintain.

  The evaluation equation for each scheme is:

  SS oriented relaying scheme_$CID_proc = NO_{RS_behind} * NO_{SS}$

  Relay link oriented relaying scheme_$CID_proc = 1 + NO_{degree} + NO_{RS_behind} * NO_{SS}$

  Relay path oriented relaying scheme_$CID_proc = 1 + NO_{R\text{-}path_behind} + NO_{SS}$

Case 1: Two-hop relay with degree 1

Figure 7-1 illustrates that the relay link and relay path oriented relaying schemes are with the processed CID in MAP of the first hop much lower than the SS orient relaying scheme, due to the helps of relay link and relay path CID assignments. However, Figure 7-2 shows that the outcomes of CID entries in each RS are with very similar and closed curves.

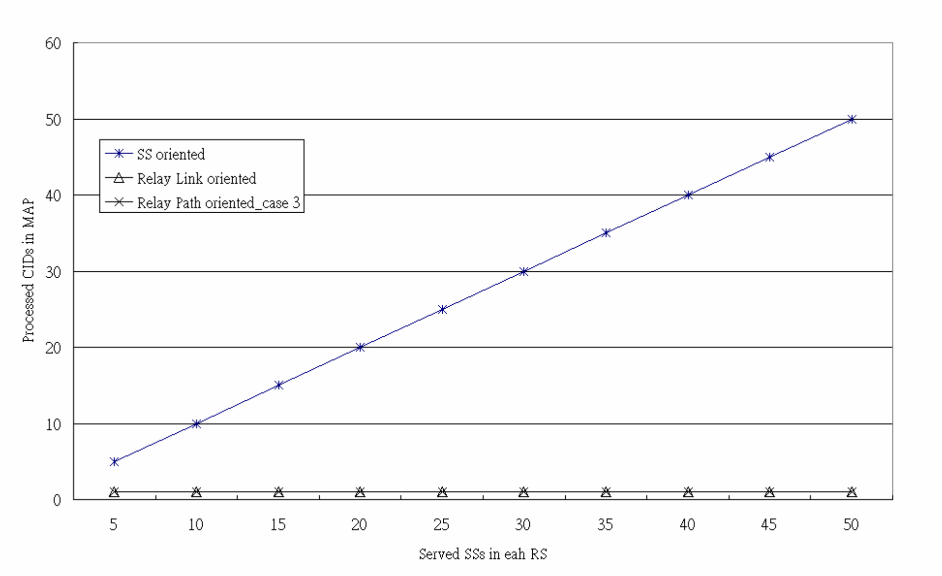

Figure 7-1, Processed CID in MAP in Case 1

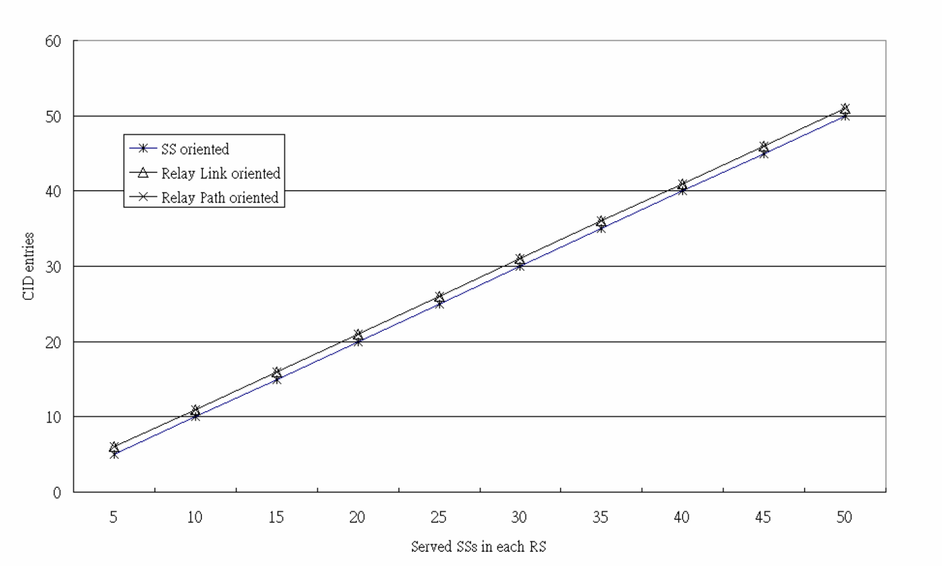

Figure 7-2, CID entries in RS in Case 1

Case 2: Two-hop relay with degree 3 model

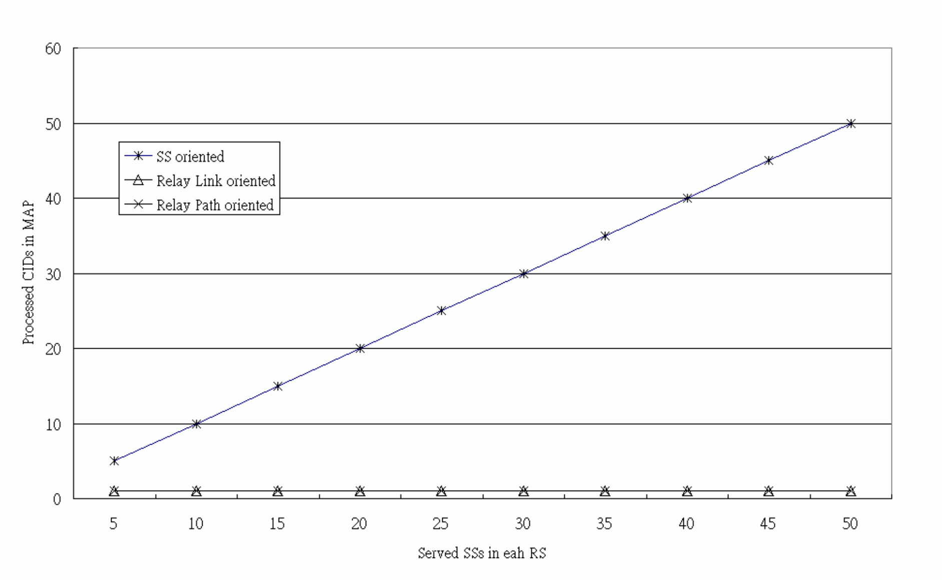

Figure 8-1, Processed CID in MAP in Case 2

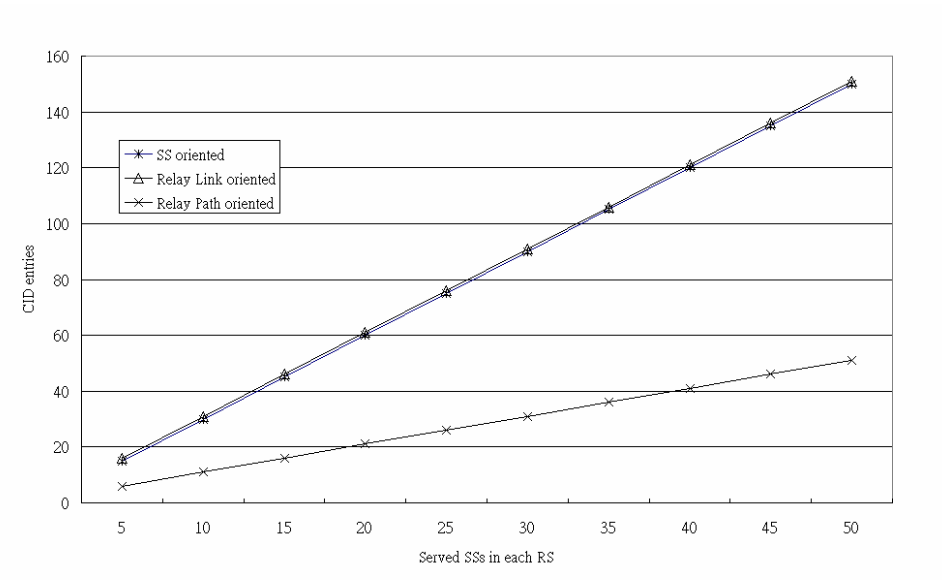

Figure 8-2, CID entries in RS in Case 3

Figure 8-1 also presents very similar results to Figure 7-1 in the processed CID in MAP of first hop due to the same reason mentioned for Figure 5-1. However, Figure 8-2 illustrates that the needed of CID entries in each RS is with very different outcomes than Figure 7-2, where SS oriented and relay link oriented relaying scheme required more CID entries than the relay path oriented relaying scheme, because the previous two relaying scheme require that each RS shall record all descendant SS CIDs into its table so that the RS can identify the burst by the SS CIDs, while the last one scheme only use the single relay path CID instead of the descendant SS CIDs. Consequently, adding the descendant degree to MR-BS or each RS reflects the adding of SSs, therefore, the SS oriented and relay link oriented relaying scheme induce the higher CID management efforts.

Case 3: **Two-hop/Three-hop** relay with degree 3 model

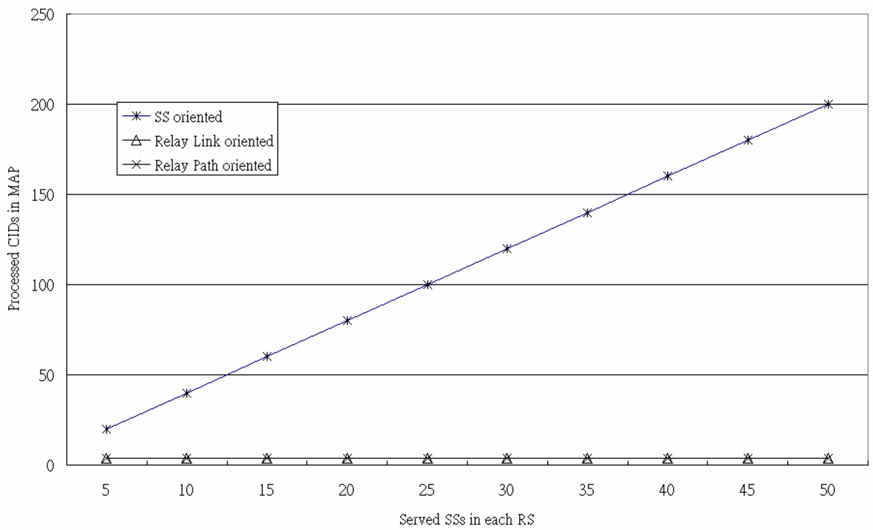

Figure 9-1, Processed CID in MAP in Case 3

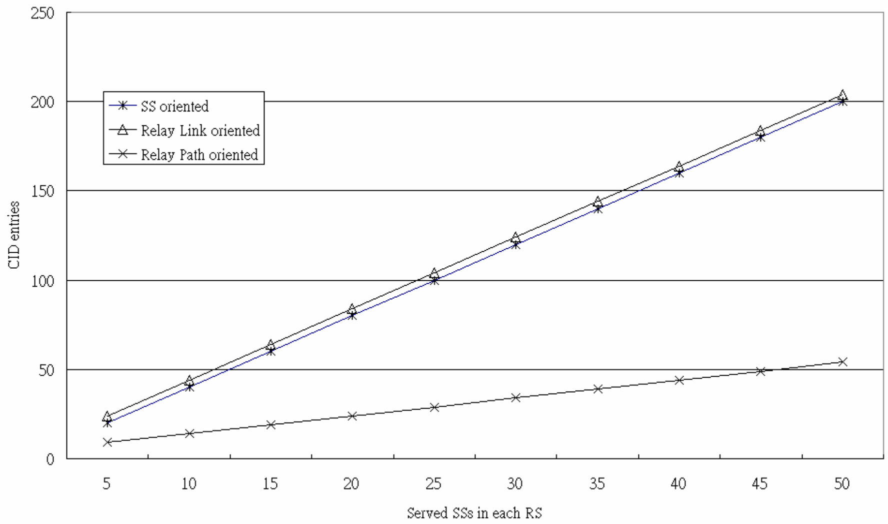

Figure 9-2, CID entries in RS in Case 3

In accordance with the observations from Figure 9-1 and 9-2, the SS oriented relaying scheme worsens the processed CID in MAP of the first hop and CID entries in RS, due to the large number of served SSs of the RS and subordinate RSs. It is easily to find that using a single CID for relay link or relay path can reduce the processing overhead in CID mapping (figure 9-1). For specific CID allocation, relay link oriented relaying scheme pay more cost in CID entries of each RS than relay path oriented relaying scheme and only the relay path oriented relay scheme can reduce the memory requirements (figure 9-2) in RS.

According to the studies of the above three cases, we can conclude that SS oriented relaying scheme is not suitable for MR networks. We further compare relay link oriented and relay path oriented relaying schemes on data processing and management overhead.

- **Burst processing overhead**
  By relay link oriented relaying scheme, each data burst relaying is associated with a relay link CID per hop. An RS shall process the received burst so that it can know where each sub-burst shall forward. After that, sub-bursts are relayed with different CIDs for different relay links. By relay path oriented relaying scheme, each data burst relaying is associated with a path CID. The path CID means a set of relay links to relay the data burst so that the intermediate RS only identify the path CIDs to know which data burst shall be relayed without data burst processing. According to the descriptions above, no CID translation is needed in each RS for the relay path oriented relaying scheme, and hence, the forwarding delay of a relay burst in the relay path oriented relaying scheme is much lower than the one in the relay link oriented relaying scheme. Besides, the CID translations of bursts are processing power and time consuming, which would increase the hardware cost.

- **Management overhead**
  Every time a SS enters or leaves the network, the corresponding relay path entry in CID table shall be updated. In relay link oriented relaying scheme, MR-BS requests each RS along the relay path to update the entry after the SS entered or left the network. By contrast, the relay path oriented relaying scheme requires that each intermediate RS needs not to be aware of the leaving of a SS, because intermediate RS only check the relay path CID when forwarding, and only the destination RS shall process the data burst and transmit the burst to the specific SS. Therefore, not all the RS along a relay path shall involved in the management process, and only the destination RS applies. So the relay path oriented relaying scheme can save more management overheads than the relay link oriented relaying scheme.

In conclusion, we can point out that the relay path oriented relaying scheme is more suitable for 802.16 Task Group j than the other two schemes.