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Re:	IEEE 80216j-07_007r2:“ Call for Technical Comments and Contributions regarding IEEE Project 802.16j”
Abstract	This document describes the route update procedures with efficient CID management.
Purpose	This contribution is provided as input for the IEEE 802.16j baseline document.
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Systematic CID Allocation and Relay Path Configuration

1 Introduction

In 802.16e, each connection (both management and data) is identified by a Connection ID (CID) [2]. There is no routing required; data is transmitted solely between the BS and the MS. In a centralized multi-hop relay system, all relay stations form a tree topology with MR-BS as the root. The routing for each MS is decided by the MR-BS. The routing path could be mainly based on the network topology and other number of factors such as measured channel qualities, QoS of each connection, fairness, etc.

This contribution proposes to use CID assignment in a multi-hop relay system as a means to indicate network topology and further help the MR-BS to perform routing path selection. In this scheme, each relay station is assigned a range of CIDs for which the relay is responsible for decoding and forwarding. The parent node will control a superset of this CID range, and any child nodes (both RS and MS) will be assigned disjoint subsets of the CID range. Because of the structure of this CID assignment, the MR-BS could compute the relay path simply based on CIDs of destination station and each relay station can recognize its packets and forward them to corresponding stations. In this way, the routing can be maintained automatically along with CID assignment and thus significantly decrease complexity, signal overhead, and path setup latency. The systematic CID allocation could also help to reduce the delay when handoff of MRS or MS occurs, which could be achieved by locating new anchor station to maintain the topology quickly.

The proposal for this implementation has the following advantages:

Simplified operation of the relay

Reduction of overheads and delay in route updates

Reuse of existing signaling to reflect topology changes due to the movement of MRSs or MSs

Quickly locating the anchor RS for fast handoff while MRSs or MSs move

2 General Description

A unidirectional connection between BS and MS or between BS and RS is established for service flow traffic, and each connection is identified by a connection identifier (CID) [2][3]. The CID for each connection is inserted within the MAC header of a packet. When it is received, first each station checks whether the CID of the packet is for itself or for its subordinate stations. Each station accepts the packet and does the process if the packet is intended to itself or its subordinate station. Otherwise, it ignores the packet and does nothing.

Each station can distinguish the received packets by examining the CID in the MAC header or in the MAP-IE, and this can be used to maintain the routing structure. By combining CIDs with the routing for each connection, the routing structure can be updated and maintained easily along with CIDs, and the overall overheads for the routing can be reduced.

The network topology may change from time to time. Generally the MR-BS updates the CID list for each RS to reflect the topology changes. CID encapsulation can be used for RSs to maintain old CIDs while waiting for updates from the MR-BS..

3 Partitioning of Integers

3.1 General Idea

To systematically assign CIDs to the MR-BS and RSs, the proposed CID allocation mechanism adopts the partitioning of the positive integers into subsets. In this section, we describe two methods of the partitioning of integers. This can be accomplished by factorization into bit partition, or contiguous blocks. The idea is to map these subsets to nodes in a network (assumed to be a tree topology) which will assist in identifying the placement of the node in the tree.

Each node of the tree represents a subset of **Z**, the set of all positive integers. The leaves of the tree are pairwise disjoint subsets of the integers. Each parent node is a superset of the union of its children. For example, in Figure 1, B D E and D H J K. The tree can grow; at a particular node, its children must satisfy two conditions. 1) the children must be subsets of the parent node; 2) the children are pairwise disjoint.

Due to this structure, any node (root, leaf, or intermediary) can determine whether a particular integer will exist in its subtree (with itself as the root). Intermediary nodes must distinguish between two types of integers; those that terminate at the node (terminal integers), and those that do not terminate at the node (non-terminal integers). We provide two examples of integer partitioning that assume only one terminal integer at each intermediary node, and briefly mention how multiple terminal integers (per intermediary node) can be attained.

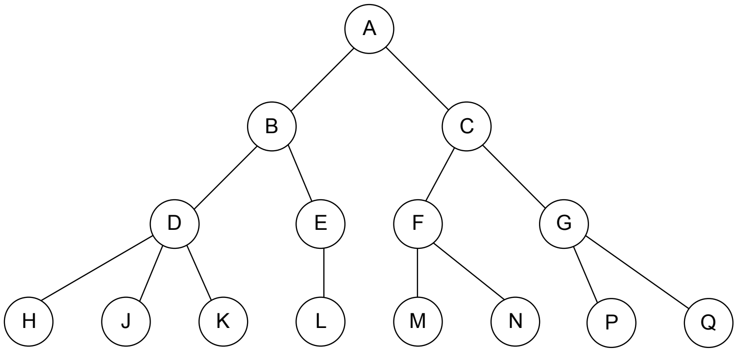


Figure 1: an example of a network tree (an abstract model)

3.2 Examples of integer partitioning: contiguous integer blocks

This is a simple implementation. The root node represents **Z**. Each of its children (1st tier nodes) are assigned a contiguous range of **Z** (and pairwise disjoint). For a particular 1st tier node (with range [p_1, p_2]), its children (2nd tier nodes) are each assigned a contiguous subset of [p_1, p_2] (and pairwise disjoint). This process continues for the entire tree. In Figure 2a, we demonstrate how the tree in Figure 1 can partition the integers using contiguous integer block methods.

In Figure 2a, the terminal integers for nodes B, C, D can be set to 1000, 2000, and 400 respectively. Allowing multiple terminal integers per intermediary node is trivial.

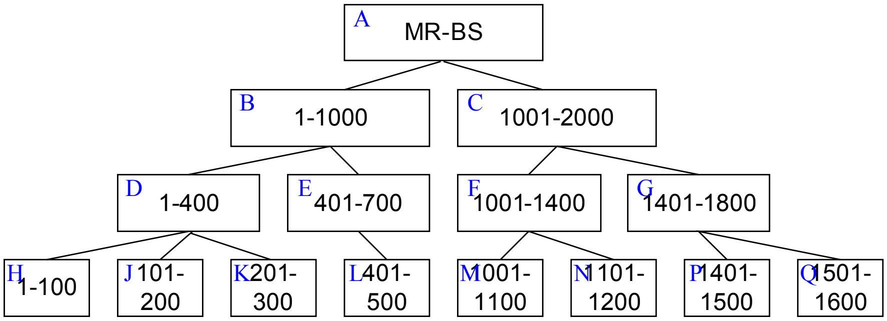


Figure 2a: partitioning of integers using contiguous blocks. The choice of range length being multiples of

100 is arbitrary.

3.3 Examples of integer partitioning: bit partition

Each decimal number could also be converted into a binary number. Assume there are at most 2^k RSs could associate with one RS or BS directly, k bits would be used to identify each RS in the same level. The 1st tier nodes that associate to the MR-BS directly would have CIDs with all possible number in lowest k bits. Their children (2nd tier nodes) is identified by left shifting k bits of parent CID and set lowest k bits. This process continues for the entire tree. In this manner, the CID (without leading 0s) of any RS will be the prefix of CIDs of all its subordinate RSs.

To convert these values into subsets of **Z** (as discussed in Section 3.1) is simple; a nth tier node will have a unique nk-bit sequence to identify itself, then the range this node could assign will be all numbers with this nk-bit sequence in the middle and begin with arbitrary number of "0"s as its prefix and with arbitrary combination of 0 and 1 as its suffix. The condition as set out in Section 3.1 is satisfied. We also demonstrate how the tree in Figure 1 can partition the integers using bit partition method in Figure 2b.

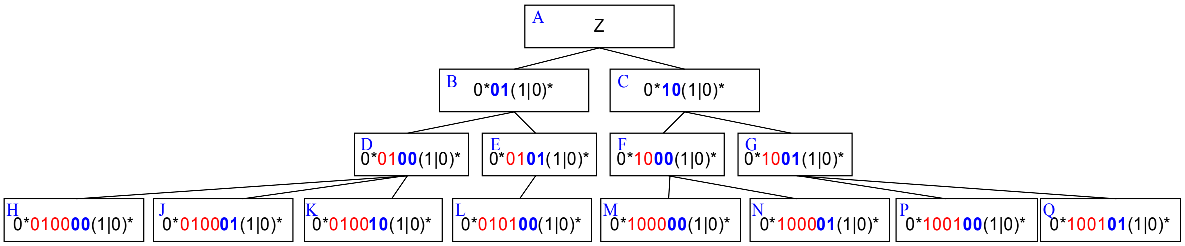


Figure 2b: partitioning of integers using bit partition.

Note that a simple way of allowing multiple terminal values at intermediary nodes is to merge nodes. For example, the logical nodes H and J can represent the same physical node.

4 CID Assignment

We describe the CID allocation for both contiguous integer partitioning method and bit partition method in the following. This structured CID assignment can be used to assign tunnel CIDs (i.e. CIDs terminating at an access RS), or RS and MS management CIDs. Our examples describe the assignment in the context of tunnel CIDs.

4.1 CID allocation using contiguous integer partitioning method

We perform this CID assignment scheme *ignoring the MS in the topology*. This method is compatible with the notion of tunnel CIDs. Tunnel CIDs are the CIDs of the terminal access RS of the appropriate QoS service, but routing is considered a separate problem. With this systematic CID allocation scheme amongst the RSs, the tunnel CIDs may be distributed smartly so that routing is embedded within the CID structure with minimal signaling.

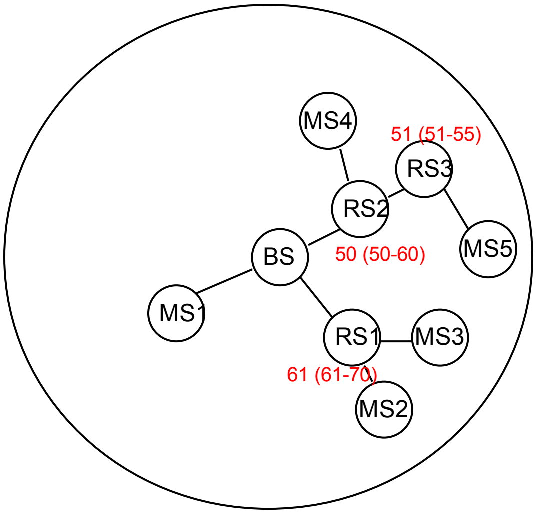


Figure 3: CID Assignment for 4.1

In Figure 3, the MR-BS indicates the range of CIDs that each RS is responsible for, as well as the CID for the connection for each RS node. For each subordinate RS, the assigned CID range has to be a subset of its connecting RS.

4.2 CID allocation using bit partition method

We first define a parameter 2^k to identify the maximum number of subordinate RSs that the MR-BS or a RS could have. If k=0, each RS could only have one subordinate RS. For 1st-tier RSs, which connect to the MR-BS directly, the MR-BS assigns IDs sequentially from 1 to 2^k as shown in Figure 4 by setting different values of the lowest k bits of the ID. We only show the lowest 8 bits of CIDs in Figure 4. For other n-tier RSs, the MR-BS left shifts k bits of its parent ID and sets the lowest k bits according to the arriving sequence of the RS. For example, RS_T and RS_U comes one after another to associate with RS_Q (ID: 00 01 00 11) after RS_R and RS_S in Figure 3. To assign an ID to RS_T, the MR-BS first perform left shift 2 bits of its parent ID and gets 01 00 11 00, and then it sets the lowest 2 bits as 10 since it is the third RS that attaches to RS_Q. Similarly, the MR-BS assigns 01 00 11 11 to RS_U after RS_T.

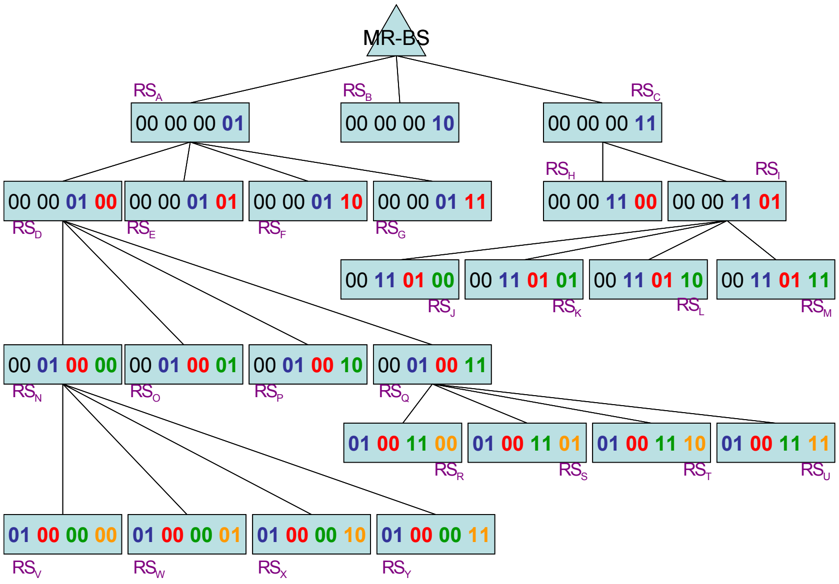


Figure 4: CID assignment for 4.2.

5 Relay Path Configuration

The proposed systematic CID allocation has significantly advantage of simple relay path configuration. In the following, we show examples how *contiguous and bit partitioning methods could be applied to relay path configuration.*

Examples of relay path configuration

We take figure 5 for example. There are two MSs, which associate to RS L (CID: 00 01 01 00) and RS G (CID: 00 00 10 01), in the network. The MR-BS has records for these two MSs and knows their serving RSs. The whole relay path could be divided into two segments: from the source RS to the MR-BS and from the MR-BS to the destination RS. For upstream frames, each RS could easily know its parent CID by right shifting k bits of its own CID. For example, the CID of access RS L is 00 01 01 00, so its parent CID is 00 00 01 01 by right shifting 2 bits of its CID. For downstream frame received from its parent RS, the RS needs to determine if it should accept, forward, or discard the frame. When the tunneling [8] [10] is applied for relaying, the Tunnel CID could be set as the CID of destination RS. Each intermediate RS could compute if the destination RS belongs to its subordinate RSs by the algorithm in Figure 6. First of all, the RS compares if the destination CID is equal to its own CID and accepts the frame if these two CIDs are the same. If the match fails, it perform k-bit right shift of the destination CID and do the comparison with its own CID. If the shifted destination CID is the same as its own CID, it forwards the frame to its subordinate RS. Otherwise, it continues do the right shift and comparison for (maximal level-current level) times and discards the frame if all matches are failed. For example, RS C would know that RS G is its subordinate RS by right shifting the destination CID once.

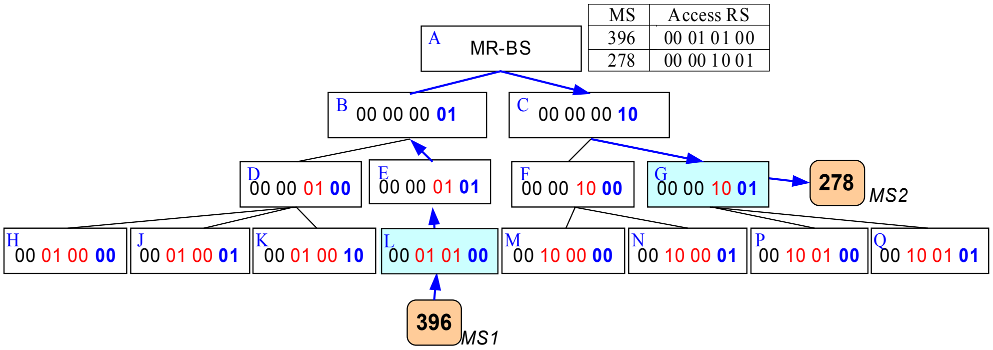


Figure 5: An example of relay path configuration using bit partition method.

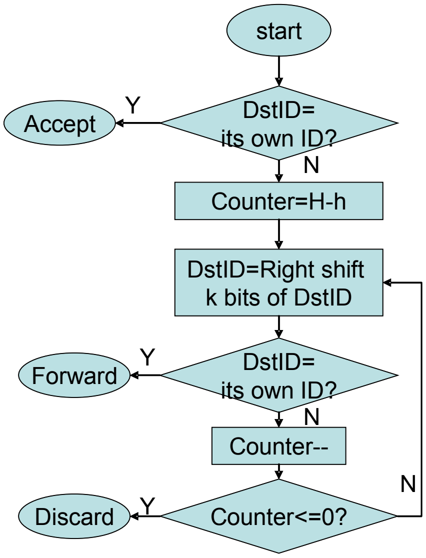


Figure 6: Subordinate RS differentiation algorithm

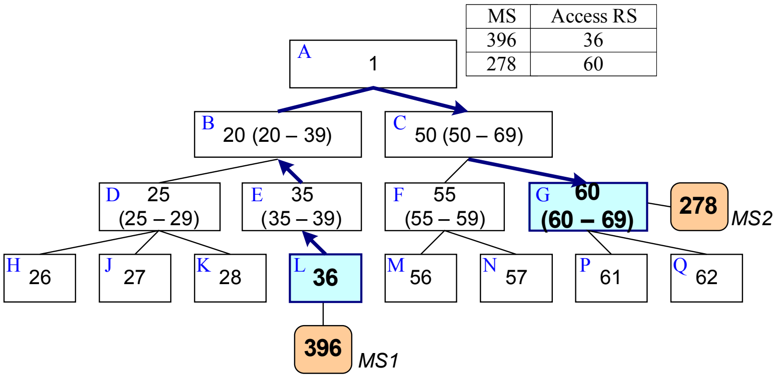


Figure 7: An example of relay path configuration using contiguous integer partitioning method. The number in parenthesis is the range of CIDs that the MR-BS could allocate to the subordinate RS.

Similarly with contiguous integer partitioning shown in Figure 7, the MR-BS keeps records of the access RS for each MS. For data directed towards MS2, the MR-BS sends the data to the access RS with CID 60. Since this CID belongs to the range of CID of the RS C, it forwards the data to the RS G. Meanwhile, the RS B ignores this data as the CID is not within its range. The similar procedure can be done on the uplink.

To support dynamic topology such as MDHO and cooperative relaying, encapsulation of CIDs [6] can be used to perform path configuration, as described in the next section.

6 CID encapsulation

The MR-BS can send updates to reflect the changes in network topology from time to time. During transition stages, the length of time required to update the CID assignment is too lengthy. Furthermore, for cases such as MDHO, the CID assignment may be temporary. In this section, a solution to adapt to such changes in topology is presented.

The general idea of CID encapsulation is to have a dynamic method for temporarily changing CIDs. For example, it allows an intermediate node, who is assigned CID B, to relay a message with CID A, which the node is not directly responsible for. The following figure describes the structure of such MPDUs.

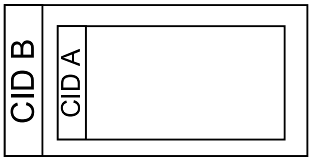
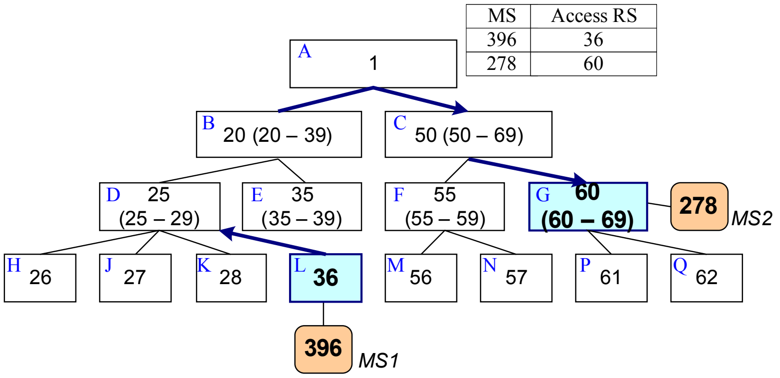


Figure 8: An inner MPDU with header CID A is encapsulated with an outer MPDU with header CID B.

In this context, the intermediate node only requires to understand the following:

- The node understands to listen to the MPDU for retransmission. This condition is satisfied because systematic CID allocation is assumed.
- The node understands how to strip out the outer header, and relay the inner MPDU. This requires minimal signaling.

The following two figures demonstrate how CID encapsulation can be used to perform changes in network topology. Node L has moved, and the BS knows to change L's parent from Node D to Node E.



MS	Access RS
396	36
278	60

Figure 9: An example of a change in topology. The BS is aware that Node L has moved, and its parent should be changed from Node E to Node D.

Figure 10: Before: Packet with CID 36 is routed to Node L. After: Packet with CID 25 is routed to Node E. Node E strips out inner MPDU, and retransmits a packet with CID 36.

It is possible for this encapsulation to occur multiple times, depending on the severity of topological changes.

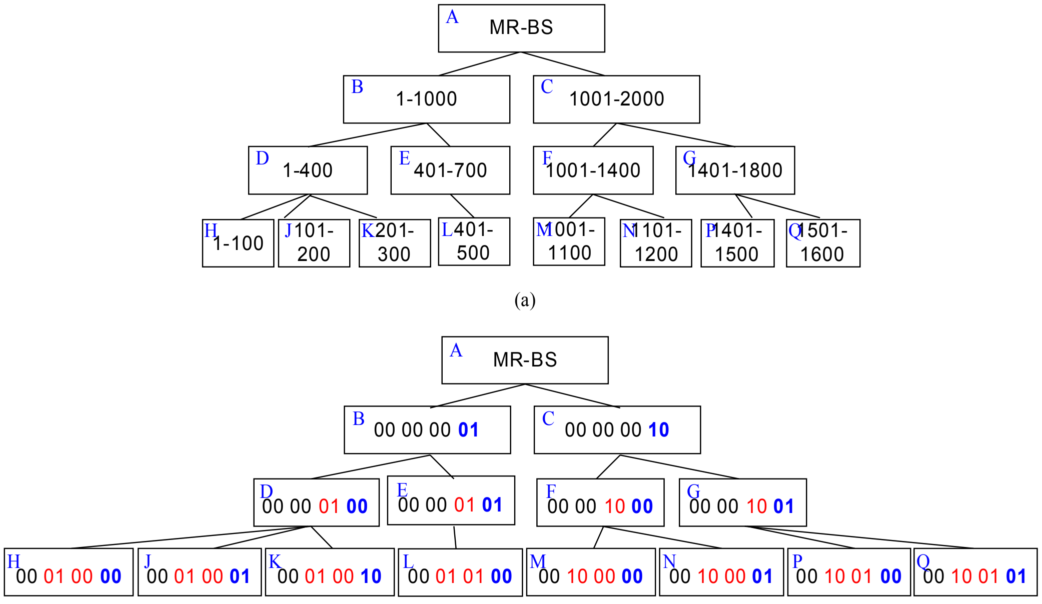
7 Proposed Text

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

[Add the following text into section 6.3.1.3]

6.3.1.3.1 Addressing Scheme for Relaying

In the procedure of network entry and initialization for a new RS, the MR-BS may systematically assign CIDs, e.g. basic CIDs, MT-CIDs, and T-CIDs, for a RS. There are two CID assignment methods: contiguous integer blocks as in Figure 6.3.1.3.X (a) and bit partition as in Figure 6.3.1.3.X (b). In the bit partition assignment, the MR-BS sets the lowest *k* bits in ascending order to RSs for RSs associated to the MR-BS directly where the maximum number of RSs the MR-BS or a RS could serve is 2^k. For other level-n RSs, which need *n* hops to reach the MR-BS, the MR-BS left shifts *k* bits of its parent CID and sets the lowest *k* bits according to the arriving sequence of the RS.



(a)

(b)

Figure 6.3.1.3.Y: CID range allocation example, (a) contiguous integer block, (b) bit partition method.

6.3.2.1 MAC header formats

[Insert the following at the end of 6.3.2.1:]

The MAC header of the PDU from the MS to the MR-BS via the RS is encapsulated by the access RS, and the MAC header of the PDU from the MR-BS to the MS via the RS is decapsulated by the access RS.

[Change the text in Table 4 as indicated:]

Table 4 – MAC header format

Syntax	Size	Notes
MAC Header() {		
HT	1 bit	0 = Generic MAC header 1 = Bandwidth request header
EC	1 bit	If HT = 1, EC = 0
if (HT == 0) {		
Type	6 bits	
reserved	1 bit	Shall be set to zero
CI	1 bit	
EKS	2 bits	
CE	1 bit	0 – no CID encapsulation 1 – CID encapsulation is used
LEN	11 bits	
}		
Else {		
Type	3 bits	
BR	19 bits	
}		
CID	16 bits	
HCS	8 bits	
}		

6.3.2.3 MAC management messages

[Insert the following into table 14]

Table 14 – MAC Management messages

Type	Message name	Message description	connection
xx	CID_ALLOC-IND	CID allocation message	Basic

[Insert the following subclause into section 6.3.2.3]

6.3.2.3.XX RS CID Allocation Indication (CID_ALLOC-IND) message

The CID_ALLOC-IND message shall be transmitted by the MR-BS to the RS during network entry/re-entry processes. When the network topology is changed or CID (re-)allocation is required, the MR-BS shall also transmit this message to related RSs to update CIDs. Upon receiving CID_ALLOC-IND, the RS shall (re-) configure CID allocation accordingly. The message format is shown in Table XX.

Table XX CID_ALLOC-IND message format

Syntax	Size	Note
CID_ALLOC-IND_Message_Format() {		
Management Message Type (TBD)	8 bits	
CID_Alloc_method	3 bits	0 : contiguous method 1 : bit partition method 2-7 : reserved
If (CID_Alloc_method = =0) {		
Start number of CID	16 bits	Starting point of the CID number
End number of CID	16 bits	End point of the CID number
}		
If (CID_Alloc_method = =1) {		
New CID for the RS	16 bits	
Hop count	8 bits	The new hop count of the RS to the MR-BS
K_Code	8 bits	The new maximum number of subordinate RSs that a RS could have
}		
}		

6.3.25 Relay path management and routing

Each relay station is assigned a range of CIDs (6.3.1.3.1) for which the relay is responsible for decoding and forwarding. The systematic CIDs are assigned by the MR-BS, and are transmitted to RSs via CID_ALLOC-IND message. During normal operation, the RS is only responsible for identifying subordinate RSs to do the forwarding.

The MR-BS is responsible for managing the entire CID allocations within the MR-cell. Each RS connected to a parent node (MR-BS or RS) is assigned systematic CIDs related to the parent node.

By assigning systematic CIDs to RSs, the MR-BS already specifies the relay routing path of the connection.

When a relay station receives a MAC PDU with the CE field set in the MAC header, it shall remove the current MAC header and forward the payload as the new PDU. If CRC is used, the BS calculates the CRC for each packet. This reduces the calculation required at each intermediary node.

8 References

[1] IEEE C802.16j-06/004r1, “Recommendations on IEEE 802.16j”.

[2] IEEE 802.16-2004, “Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems”.

[3] IEEE 802.16e-2005, “Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands *and* Corrigendum 1”.

[4] IEEE C802.16j-06/014r1, “Harmonized definitions and terminology for 802.16j Mobile Multihop Relay"

[5] IEEE C802.16j-06/015, “Harmonized Contribution on 802.16j (Mobile Multihop Relay) Usage Models"

[6] IEEE C802.16j-07-126, “Routing with CID Encapsulation”

[8] IEEE C802.16j-06/274, “Proposal on addresses, identifiers and types of connections for 802.16j”.

[9] IEEE C802.16j-06/254, “Fast Connection Establishment and Maintenance with Relays”.

[10] IEEE C802.16j-06/170, “Connection Identification and Transmission for Relay Support”