Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Systematic relay station identification allocation and relay path configuration mechanism for IEEE 802.16j (Multi-hop Relay)
Date Submitted	2006-11-7
Source(s)	Yuan-Ying Hsu Telcordia Applied Research Center Taiwan Co., Taipei, Taiwan yyhsu@tarc-tw.research.telcordia.com Jen-Shun Yang, Tzu-Ming Lin, Wern-Ho Sheen, Fang-Ching Ren, Chie Ming Chou, I-Kang Fu Industrial Technology Research Institute (ITRI)/ National Chiao Tung University (NCTU), Taiwan 195,Sec. 4, Chung Hsing Rd. Chutung, Hsinchu, Taiwan 310, R.O.C. jsyang@itri.org.tw
Re:	IEEE 802.16j-06/027: "Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	This contribution proposes a MAC layer address allocation mechanism and introduce its benefit on relay path management for IEEE 802.16j Multi-hop Relay system
Purpose	Propose a MAC layer address allocation mechanism for relay path management in IEEE 802.16j
Notice	
Release	
Patent Policy and Procedures	

Systematic relay station identification allocation and relay path configuration mechanism for IEEE 802.16j (Multi-hop Relay)

Introduction

This contribution proposes MAC layer ID allocation and relay path configuration mechanism to be used in the Multi-hop Relay (MR) amendment to IEEE Standard 802.16e-2005. A MR Network is a multi-hop network which forms a tree topology with MR-BS as the root. Each relay station (RS) is required to have an ID (i.e., MAC address) or Connection ID (CID) for addressing, and relay paths must be identified to send traffic to a mobile station (MS) under a destined RS. In this contribution, we jointly consider addressing and routing issues to propose a systematic CID allocation and relay path configuration mechanisms. Since the proposed CID allocation mechanism systematically assigns CIDs to RSs, the CIDs of RSs could represent the MR network topology. Therefore, the CIDs of RSs could also help BS or RSs to configure relay paths in distributed manner. In the past centralized solutions, a centralized server like the MR-BS in the MR network needs to have whole network topology before finding a relay path. The network topology could be stored statically at server side or be obtained from network dynamically, which causes both storage cost or/and transmission cost. In our proposed solution, the MR-BS could simply be aware of the network topology thoroughly according to the CIDs of RSs without maintaining network topology and could compute a relay path to a destined RS by its CID without exchanging information with descendent RSs. When an MS performs handoff procedure from one RS to another RS due to signal strength or QoS issue, the proposed mechanism could timely update information in the MR-BS and find the anchor RS to redirect traffic to the new RS. As a result, handoff procedure could be very time and signal efficient.

Table of Contents

1 Overview

1.1 Scope

Based on the 802.16j PAR and 5 criteria [1], the scope of this project focuses on the OFDMA physical layer and medium access control layer enhancements to IEEE Std 802.16 for licensed bands to enable the operation of relay stations. The project aims to expand coverage and to enhance throughput and system capacity for IEEE802.16 systems. It is expected that the complexity of relay stations will considerably less than that of legacy IEEE 802.16 base stations and will enable rapid deployment and reduce the cost of system operation. To support backward compatibility of IEEE Std 802.16 family, subscriber station (i.e., MS) specifications are not changed. In this contribution, we will jointly consider addressing and relay path issues of RSs for relaying purpose as well as mobility support

1.2 Purpose

Refer to IEEE802.16j-06/041 [2], the nodes in MR systems include MR-BS, BS, RS, MRS, and MS. The communication path in this network is divided into two parts: an 802.16j radio link between an MR-BS and an RS or between a pair of RSs is called relay path; an 802.16 radio link that originates or terminates at an MS is called access link. In this contribution, we focus on how to find a relay path from the MR-BS to a destined RS to which the MS attaches. Although an MR network is a multi-hop network, it is not probable to apply routing protocols for MANET to MR network directly. The protocols designed for MANET are most distributed ones and ask each node maintain routing information or periodically exchange information with neighbors, which violates the simplicity and efficiency principles of relay stations.

To design a simple and efficient relay path configuration in a MR network, we first design a prime-based identification allocation mechanism to systematically assign basic Connection Identifications (CID) to the MR-BS and RSs during the ranging procedure in the *network entry and initialization time*. The proposed mechanism could also be applied for primary and secondary CID allocation. The CID of RS could further assist in relay path configuration to allow MR-BS or RS compute a relay path by itself simply according to the CIDs of the source RS and the destination RS. Therefore, RSs do no need to periodically exchange routing information or send any request for relay path solicitation, and thus significantly decrease complexity, signal overhead, and path setup latency.

Besides configuring a relay path, the MR network needs also solve mobility issue when an MS handoffs from one RS to another RS. Since our prime-based identification allocation mechanism could assign RSs CIDs to represent the whole network topology, the new RS that the MS attaches could quickly find the anchor RS of the old and new relay path. The anchor RS could immediately redirect traffic to the new RS with minimum handoff delay.

2 Relay Station identification allocation mechanism and relay path configuration

2.1 Prime-based identification allocation mechanism

To systematically assign CID to the MR-BS and RSs, the proposed prime-based identification allocation mechanism adopts characteristics of prime numbers. According to the canonical factorization theorem [2], each integer can be expressed as a product of a unique sequence of prime numbers. Similarly, we can make all integers form a tree like Figure 1 and each integer will definitely locates at a decisive place in the tree. This characteristic enables us to assign CIDs in a MR network and have network topology at the same time. Before describing the proposed mechanism, we first define prime factorization sequence, denoted as pfSeq(n), of an integer n in Definition 1. We can claim that the prime factorization sequence of an integer is unique based on the canonical factorization theorem. For example, integer 12 is equal to 2*2*3, and thus pfSeq(12)=(2, 2, 3).

Definition 1: The prime factorization sequence of an integer n>1, denoted as pfSeq(n), is a non-decreasing ordered multi-set of the prime factors of n, such that $pfSeq(n) = (p_0, p_1, ..., p_m)$, where $p_i < p_j \forall i < j$ and $\prod_{i=0}^{m} p_i = n.$

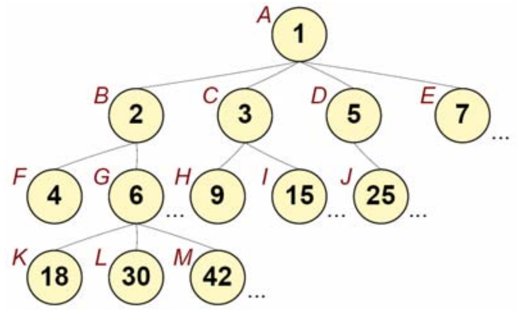

Figure 1: An example of CID allocation tree

Figure 1 gives an example of CID each RS can assign according to the proposed prime-based identification allocation algorithm. The MR-BS is the root in a MR network, and thus it configures its own CID as 1. The MR-BS allocates all prime numbers, in ascending order, to RSs which decides to attach to it. For a RS with an CID n and a corresponding pfSeq(n)=(p_0, p_1, ..., p_m), it can assign the CID each of which equals to its own CID multiplied by a prime number, starting from its largest prime factor p_m. Each RS can also derive the CID of its parent simply by dividing its own CID by the largest prime factor of its own CID. For example, RS G in Figure 1 has the CID 6, and the largest prime factor of 6 is 3. The sequence of CIDs RS G can assign is 6*3, 6*5, 6*7, and so on up to the largest CID bounded by the field length of CID. RS G can also find the CID of its parent as 6/3=2. Since the prime factorization sequence of each integer or CID is unique, no two RSs can generate the same CID by running the proposed prime-based identification allocation algorithm.

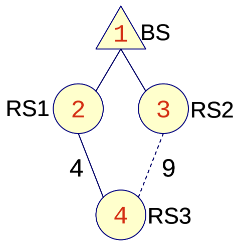

Figure 2: CID allocation example of a new RS

We then describe how to apply the proposed prime-based identification allocation mechanism in an MR network for the network entry and initialization of a new RS or the handover procedure of an MRS. In the case of network entry and initialization for a new RS, the temporary associated RS for initialization could be determined after the ranging of the new RS. At this time, the MR-BS shall assign CIDs (i.e., basic CID, primary CID, secondary CID) to the new RS by performing the proposed prime-based identification allocation mechanism for the rest of initialization procedure. However, according to the topology configuration, the preceding RS of the new RS may differ from temporary associated RS for initialization, so the RS network re-entry procedure presented in [10] shall be proceeded in order to determine the actual selected preceding RS for the new RS. Thereafter, the MR-BS shall assign a new CID to the new RS if required.

Due to the centralized CID management manner, the MR-BS must maintain the whole prime-based CID allocation tree including each RS's sequence of prime numbers and the corresponding *allocation status* (a pointer to the prime number used for generating the last assigned address). Figure 2 illustrates a CID allocation example of how the new coming RS acquires an address. Figure 3 depicts the corresponding message flows for centralized CID allocations after the completion of RS network re-entry procedure. We present two cases in each figure, which are Case 1: the selected preceding RS is the same as the temporary associated RS for initialization, and Case 2: the selected preceding RS is different from the temporary associated RS for initialization. A new message *RLY_TPY-IND* is invented to manage the preceding RS assignment and CID allocation.

For Case 1 in Figure 3, the MR-BS determines the selected preceding RS still remains RS1 and sends a *RLY_TPY-IND* with CID field = 4 to inform the unchanged of preceding RS (RS1) for the new RS.

For Case 2 in Figures 3, The MR-BS determines the selected preceding RS is RS2 which is different from the temporary associated RS for initialization. It must issue the new CID with CID field = 9 carried by two *RLY_TPY-IND* messages to RS2 and the new RS separately. Upon receiving *RLY_TPY-IND* message, the RS2 recognizes that a new RS with CID = 9 will associate with it soon, and the temporary associated RS (RS1) shall forward the message to the new RS. Thereafter, the new RS shall start to associate with RS2.

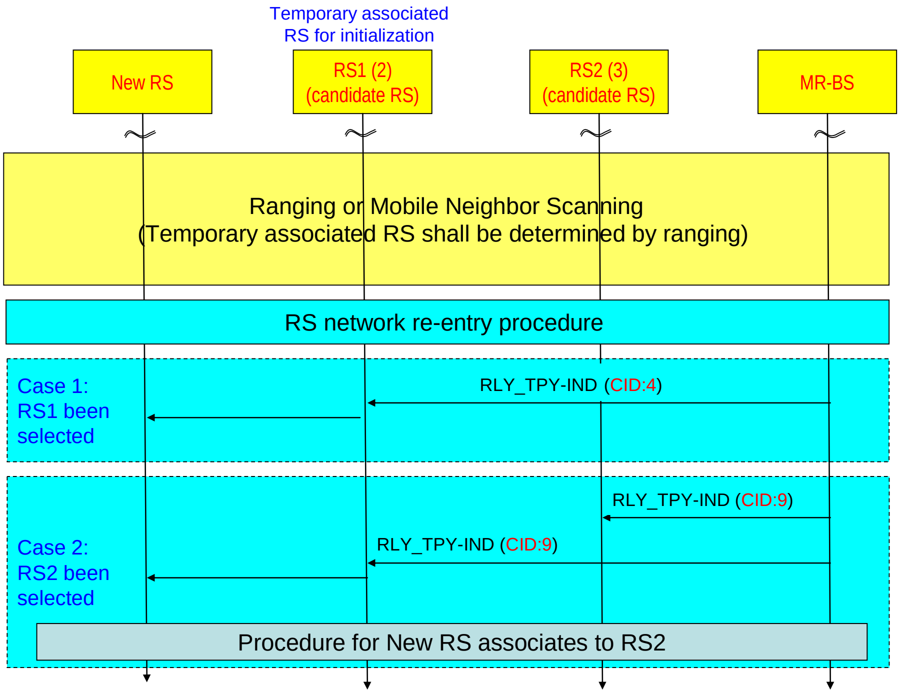

Figure 3: Centralized CID allocation Message flow of a new RS

Figure 4 gives an example of CID allocation results for a MR deployment with seven RSs. The root is the MR-BS. The dotted line between two stations represents the coverage overlapping. We assume the order of RSs joining the network is from node RS_A to node RS_G. First of all, the MR-BS configures its own CID as 1 in step (a). RS_A and RS_B then joins the MR network and obtain CIDs 2 and 3 respectively as shown in step (b). In step (c), RS_D could associate with RS_A and RS_B. The MR-BS could choose one RS (e.g., RS_A) by some other considerations like load-balancing consideration, and assign the CID 6 to RS_D. Similarly, the MR-BS could assign CIDs to RS_E in step (c), RS_F and RS_G in step (d) in the same manner. Consequently, Figure 5 depicts the CID allocation tree of Figure 4.

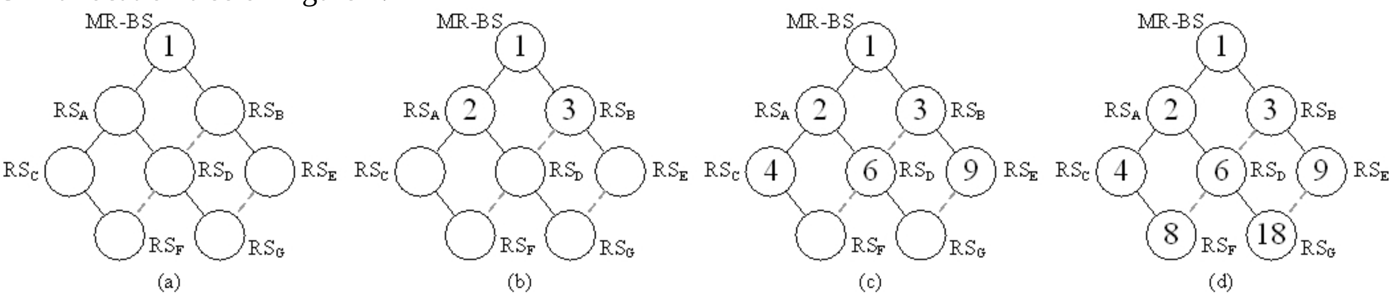

Figure 4: An example of CID allocation result

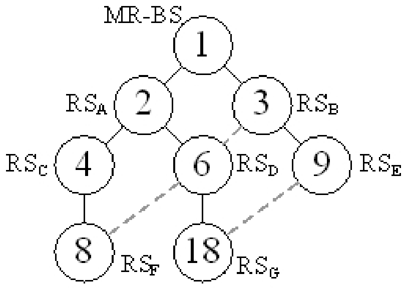

Figure 5: The CID allocation tree.

2.2 Prime-based relaying configuration mechanism

The proposed prime-based relaying configuration mechanism can enable each node configure routing paths to all other local nodes simply according to the source and destination CIDs. Since the prime factorization sequence of each integer is unique, each node is uniquely located in the CID allocation tree. Once a node needs to send packets, it knows where the destination node is by its CID. Therefore, no routing information needs to be exchanged between nodes to find a routing path. Before describing the proposed routing protocol, we define *Sequence GCD* of two integers in the Definition 2 first. Nodes can find their routing paths by computing the sequence GCD of source and destination CIDs.

Definition 2: Given two integers *m* and *n* that $pfSeq(m)=(p_0, p_1, p_2, ..., p_i)$ and $pfSeq(n)=(q_0, q_1, q_2, ..., q_j)$, sequence GCD of *m* and *n* denoted as *seqGCD(m,n)* is defined as follows:

$seqGCD(m,n)=\prod_{k=0}^{k=l} r_k$, where sequence $y=(r_0, r_1, ..., r_l)$ is the longest common prefix of *pfSeq(m)* and *pfSeq(n)*. If sequence $y=\phi$, *seqGCD(m, n)=1*.

e.g.,

seqGCD(16, 12)=2*2=4
- pfSeq(16)=(2, 2, 2, 2)
- pfSeq(12)=(2, 2, 3)
- the longest common prefix of *pfSeq(16)* and *pfSeq(12)* is *(2, 2)*.

seqGCD(18, 15)=1
- pfSeq(18)=(2, 3, 3)
- pfSeq(15)=(3, 5)
- the longest common prefix of *pfSeq(18)* and *pfSeq(5)* is ϕ.

The value of *seqGCD(source CID, destination CID)* is the product of the longest common prefix of *pfSeq(source CID)* and *pfSeq(destination CID)*, and thus it represents the least common ancestor (LCA) of the source and destination node. By computing the sequence GCD value of source and destination CIDs, each node can configure the routing path into two segments: from source node to the LCA and then to the destination node.

For applying prime-based relaying configuration mechanism in MR network, all RSs do not need to record anything and the source RS can determine the whole routing path due to the connection oriented characteristic in IEEE 802.16 series specifications. For example, Figure 6 (a) is the CID allocation tree of a MR and Figure 6 (b) depicts the possible relay paths of RS O to RS P and RS M to RS I.

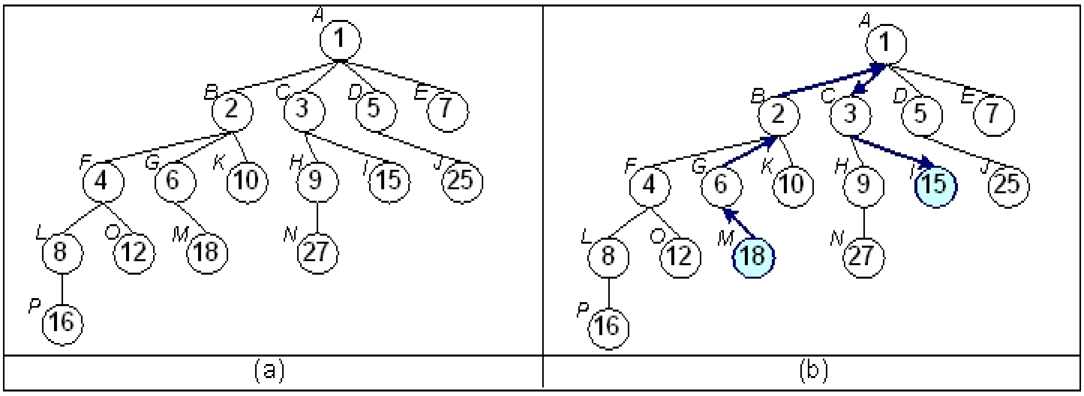

Figure 6: An example of setting routing path: (a) CID allocation tree; (b) Routing paths while applying prime-based relaying configuration mechanism.

- **Prime-based relaying configuration algorithm**

In the prime-based relaying configuration mechanism, the MR-BS and RSs purely proceed along branches of the CID allocation tree to obtain relay paths without either exchanging routing information or recording any information. We will describe the detail procedures below in two scenarios.

```
// setting up the relay path from the MR-BS to dst
int primeFactors []
primeFactors = pfSeq(dst)
for(int k=0; k< number of elements in primeFactors; k++){
  child =1 //CID of MMR-BS=1
  for(int i=0; i<k; i++){
        child = child*primeFactor[i]
  }
  add child into the relay path
}
```

Figure 7: Setting relay path from the MR-BS to the destination RS with ID *dst*

- Scenario 1: Intra MR network scenario:

In this scenario, both source and destination node are in the same MR network, and the relay path must go through the MR-BS. Specifically, the relay path will be in the form of MS-RS*-BS-RS*-MS. The source RS is the access RS of the source MS, whereas the destination RS serves the destination MS. 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. In the first segment, the source RS or other interim RSs could simply relay traffic to its parent RS. Assume pfSeq(dst) =(p0, p1, p2, ..., pm), the MR-BS could compute pfSeq(dst) to derive the second segment of relay path as $(\prod_{i=0}^{i=1} p_i, \prod_{i=0}^{i=2} p_i, \ldots, \prod_{i=0}^{i=m} p_i)$. Therefore, the MR-BS can recursively add these RSs into the relay path as illustrated in Figure 7.

We take Figure 6 for instance to describe how RS M(18) sets the routing path to RS I(15) in this scenario. RS M(18) first recursively add addresses of parent RSs, 6, 2, and 1, into its relay path until reaching the MR-BS. MR-BS then factorizes the destination address to computes *pfSeq(15)=(3, 5)*. Obtaining these prime factors, the RS M could recursively add *1*3* and *1*3*5* into the relay path and get the whole relay path (6, 2, 1, 3, 15) to RS I(15).

- Scenario 2: Inter MR network scenario:

This scenario discuss about how to configure a relay path when the source or destination node is outside from the MR network. We first consider the case that the destination node is not in the MR network. Since the serving RS of the source node could not find the destination RS in the MR network, it simply forward traffic to the MR-BS by applying the first segment relay path establishment algorithm defined in the second scenario. In the other case, the source node is not in the MR network. The packet will be routed to the MR-BS via routing mechanisms defined in the Internet and IEEE 802.16 series specifications. While the MR-BS receive traffic, it first identify the serving RS of the destination MS, and apply the second part of algorithm defined in the second scenario to find the relay path to the serving RS.

Figure 8 gives an example of two scenarios described above. There are three MSs in the MR network, and the MR-BS records the access RSs for these MSs. We first use connection from MS 1 to MS 2 to elaborate scenario 1. RS 1 sends traffic directly to the parents until to the MR-BS. Upon receiving traffic, the MR-BS looks up the table and finds the access RS of destination MS 2 is RS 3, and it runs the algorithm we described above and redirects traffic to RS 3. In the second scenario, a CH outside the MR network wants to communicate with MS 4, and traffic is routed to the MR-BS. The MR-BS first checks the table and finds the serving RS of MS 4 is RS 6, so it runs the algorithm to have the relay path (2, 6).

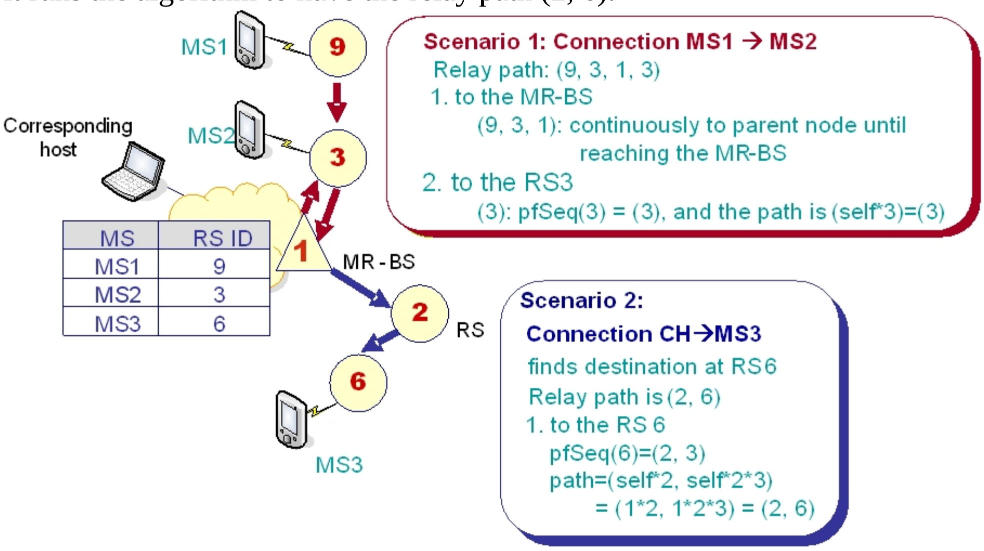

Figure 8: Examples of three cases of relay path configuration.

Figure 9 gives an implementation example of using proposed prime-based relaying in the scenario illustrated in [9]. All RSs have a CID assigned by the MR-BS according to the proposed prime-based identification allocation algorithm. By adopting to the identification and transmission schemes in [9], a burst is transmitted in two sections: one section is the relay path between MR-BS and the access RS of the served SS (i.e., destination RS) for which the relaying is identified by the CID of the destination RS, another section is the access link of the served SS for which the access link is accessed according to the CID of served SS. In Figure 9, we give a downlink relaying example where MR-BS could set the CID of destination RS (i.e, access RS) in the DL-MAP. The RS could simply check if the destination RS is its subordinate RS according to the MOD operation (denoted as "%") between the destination RS CID (***dst***) and its own CID (***self***) as shown in Figure 10. Therefore, each RS does not need to maintain a CID list of all its subordinate RSs, and it does not need to process the burst and search the CID table for further forwarding while receiving every single burst. As the result, the prime-based relaying solution could increase the transmission efficiency in MR network.

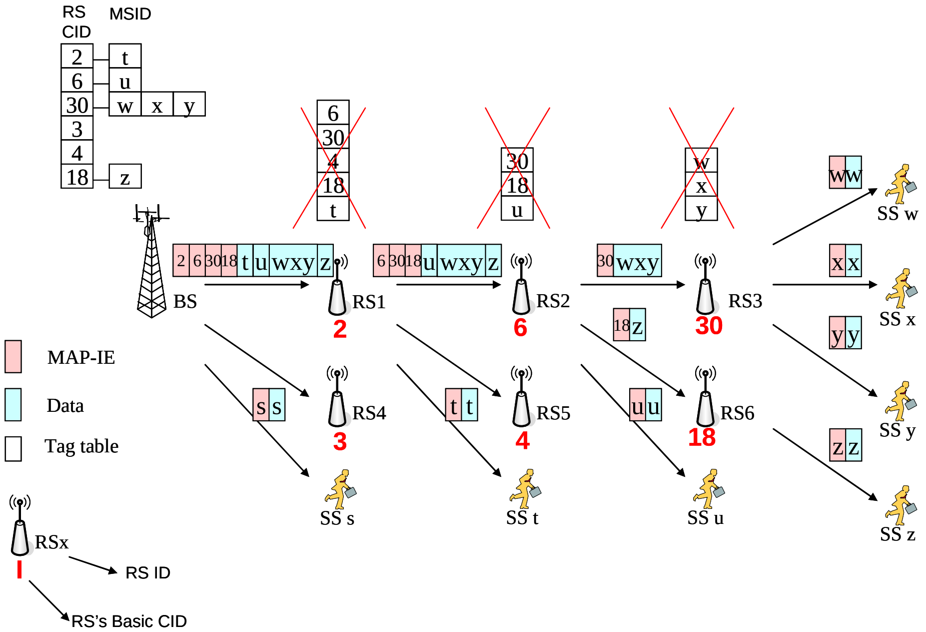

Figure 9: Implementation example of using prime-based relaying in Tag Switch Relaying.

```
int smallerPrime []
smallerPrime = all prime numbers smaller than the smallest prime factor of  self
descendent =true;
If(dst%self==0){
        for (int i=0; i< number of elements in smallerPrime  ; i++)}{
                if(dst%smallerPrime [i]==0){
                        descendent =false;
                        break;
                }
        }
}else{
        descendent =false;
}
```

Figure 10: Subordinate differentiation algorithm

2.3 Prime-based mobility management

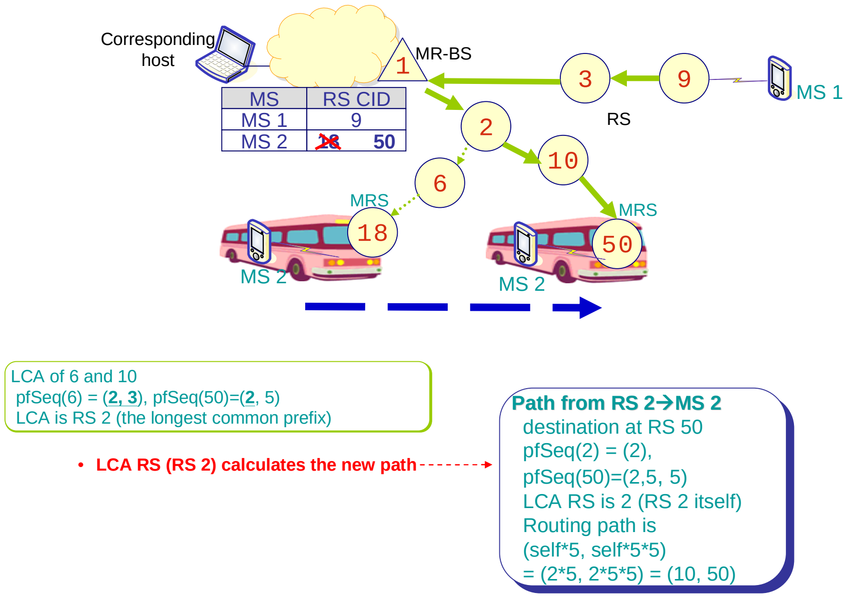

Figure 11: Example of MRS handover

Since prime-based identification allocation mechanism can enable BS to efficiently find out the anchor RS (i.e., the LCA RS) of two subordinate nodes by GCD method, it can benefit the procedure of mobile handover. For example, a Mobile Relay Station (MRS) in Figure 11 is deployed on a bus to make all MSs on the bus be able to access the internet. A new message *MOB_ANCO-IND* is invented for MR-BS to indicate the anchor RS of Serving RS and Target RS. Below are the procedures when MRS handovers between RSs:

1. The procedures for the scanning of neighbor RS/MR-BS.
2. Once Target RS has been determined (i.e., RS 10 in this example), MR-BS can simply find out the anchor RS (i.e., the LCA RS) between Serving RS (RS 6) and Target RS (RS 10), which is RS 2 in this example.
3. MR-BS sends *MOB_ANCO-IND* to indicate the anchor RS (i.e., RS 2 in this example), so that the anchor RS can start to buffer the data traffic.
4. MR-BS sends *RLY_TPY-IND* message to pre-allocate a new CID (50) for MRS.
5. Anchor RS calculates a new relay path between itself to the Target RS by prime-based relaying configuration mechanism and then processes the bandwidth reservation for the new path.
6. MRS handovers to Target RS (the detailed handover procedure is keeping an open issue here).
7. After MRS completes the handover to the Target RS, anchor RS forwards the buffered data traffic to Target RS.
8. MR-BS updates the location mappings entry in accordance with the new CID (50) of MRS. This action makes the sequential data traffic correctly transmitted to the new location of MRS.

The benefits of finding anchor RS are described as below:

- Forwarding data traffic when MRS performs handover can be buffered at anchor RS, so it can release the buffering loads in MR-BS and easily combine with the buffering mechanism for HARQ.
- Since the new relay path can be clearly determined, the bandwidth reservation can only be required along the new relay path between anchor RS and Target RS.

3 Proposed Text

3.1 *Prime-based identification allocation mechanism*

---Start text proposal---

[Add the following text into section 6.3.1.3]

6.3.1.3.1 Addressing Scheme for Relaying

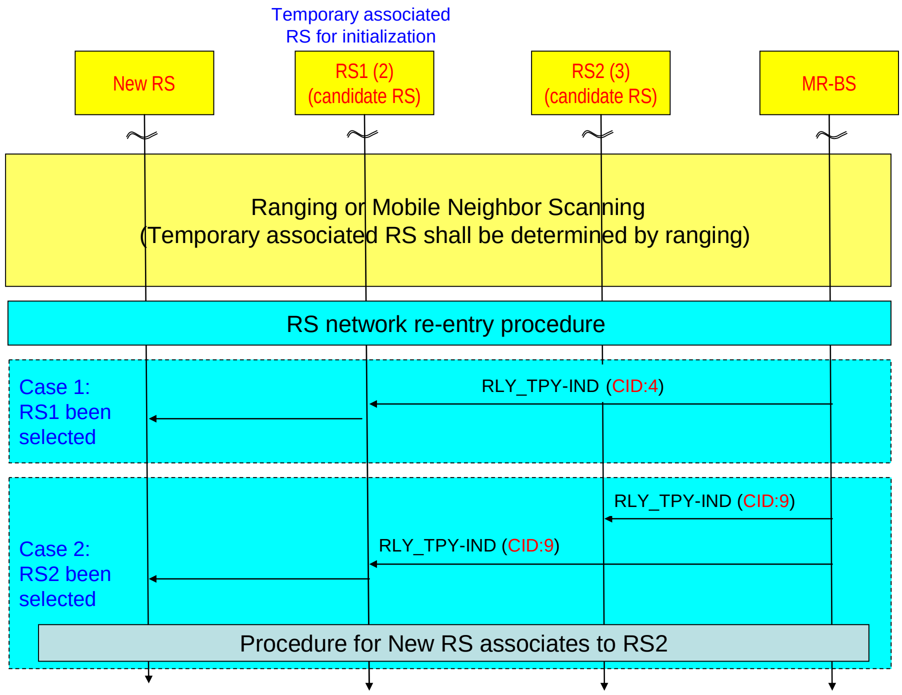

Figure 6.3.1.3.X: CID allocation Message flow of a new RS

In the procedure of the network entry and initialization for a new RS, the temporary associated RS for initialization could be determined after the ranging of the new RS. At this time, the MR-BS shall assign CIDs (i.e., basic CID, primary CID, secondary CID) to the new RS by performing the prime-based identification allocation mechanism for the rest of initialization procedure. However, according to the topology configuration, the preceding RS of the new RS may differ from temporary associated RS for initialization, so the RS network re-entry procedure shall be proceeded in order to determine the actual selected preceding RS for the new RS. Thereafter, the MR-BS shall assign a new CID to the new RS if required. Figure 6.3.1.3.X depicts the corresponding CID allocation message flows after the completion of RS network re-entry procedure.

Case 1: the selected preceding RS is the same as the temporary associated RS for initialization. The MR-BS determines the selected preceding RS still remains RS1 and sends a *RLY_TPY-IND* with CID field = 4 to inform the unchanged of preceding RS (RS1) for the new RS.

Case 2: the selected preceding RS is different from the temporary associated RS for initialization. The MR-BS determines the selected preceding RS is RS2 which is different from the temporary associated RS for initialization. It must issue the new CID with CID field = 9 carried by two *RLY_TPY-IND* messages to RS2 and the new RS separately. Upon receiving *RLY_TPY-IND* message, the RS2 recognizes that a new RS with CID = 9 will associate with it soon, and the temporary associated RS (RS1) shall forward the message to the new RS. Thereafter, the new RS shall start to associate with RS2.

To systematically assign addressing or CID to the MR-BS and RSs, the MR-BS runs prime-based CID allocation algorithm. The MR-BS configures itself with CID 1. For RSs associated to the MR-BS, the MR-BS allocates prime numbers as CIDs in ascending order to RSs until to the maximum number of CIDs. For a RS associated to another RS with CID n, the MR-BS factorizes $n= \Sigma p_i$, where all p_i are prime numbers and $p_m \leqq p_n$ if $m<n$. The MR-BS assigns RSs, which associate with RS with CID n, CIDs each of which equals to n multiplied by a prime number, starting from the largest prime factor p_m of n. Figure 6.3.1.3.XX is an example of CID allocation result. In the CID allocation space of m, the first n CIDs could be assigned to RSs and the rest ones are allocated for SSs or MSs, or the whole CIDs space could be shared by RSs and SSs (MSs).

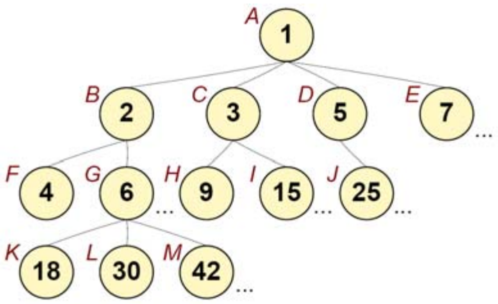

Figure 6.3.1.3.XX: An example of prime-based CID allocation tree

---End text proposal---

3.2 *Prime-based relaying configuration mechanism*

---Start text proposal---

[Add the following text into section 6.3.25]

6.3.25.1 Relaying Path Management and Routing

Each RS shall be able to serve all MSs and SSs that associate with it to relay traffic from the source RS (RS_s) to the destination RS (RS_r). If a RS_s does not know which RS_r is the access RS of the destination SS (or MS), it could ask the MR-BS if necessary. The MR-BS shall be capable to be aware of the access RS of the destination SS and configure a relay path to the RS_r along the branches of the CID allocation tree. Assume the CID of RS_r is n, we define prime factor sequence of n, denoted as *pfSeq(n)*, $pfSeq(n) = (p_0, p_1, ..., p_m)$, where $p_i < p_j \forall i < j$ and $\prod_{i=0}^{m} p_i = n.$

There are two types of relay path configuration as follows:

- Relaying type 1: Intra-MR relaying: the source station and destination station are in the same MR network.
- Relaying type 2: Inter-MR relaying: the source station and destination station are in the different MR network.

6.3.25.1.1 Relaying type 1: Intra-MR relaying

When the source and destination nodes are both in the same MR network, the RSs needs to relay traffic to the RSr. First of all, the RSs shall relay traffic to the MR-BS by sending traffic to its parent RS. Each RS simply relay traffic destined to the MR-BS to its parent RS. Upon receiving the traffic from the RSs, the MR-BS also checks the RSr for the destination node, and relay traffic to the RSr as illustrated in Figure 6.3.25.1.Y.

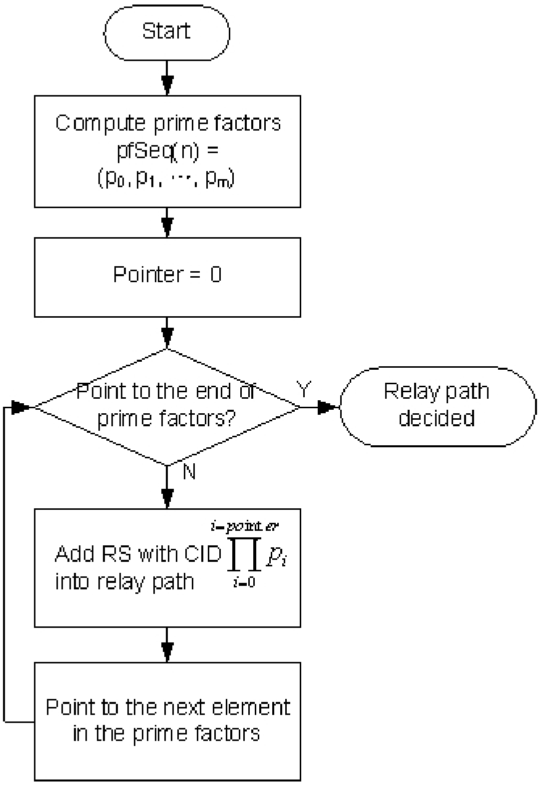

Figure 6.3.25.1.Y: Relaying from the MR-BS to the RSr with CID=*n*.

6.3.25.1.2 Relaying type 2: Inter-MR relaying

This type of relaying defines relaying procedure when a source or a destination is not in the same MR network as the MR-BS.

In the case of the source is not in the MR network, the MR-BS shall receive the traffic from the core network. It checks the access RS (RS_r) of the destination SS. The MR-BS shall send traffic to the RS_r along the branches of the CID allocation tree $(\prod_{i=0}^{i=1} p_i, \prod_{i=0}^{i=2} p_i, ..., \prod_{i=0}^{i=m} p_i)$ as illustrated in Figure 6.3.25.1.Y.

In the other case that destination node is not in the MR network, the RSs sends traffic recursively to the parent RS until to the MR-RS. Upon receiving traffic from the RSs, the MR-BS checks the table but finds no entry for the destination node. The MR-BS concludes the destination node is outside of the MR network and routes traffic to the core network.

[Change the following text in 8.4.5.3]

CID

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

---End text proposal---

3.3 *Prime-based mobility management*

---Start text proposal---

[Add the following text into section 6.3.22.4]

6.3.22.4 Mobile Relay Station Handover

6.3.22.4.1 Mobile Relay Station Handover using Prime Addressing Mechanism

Since prime-based identification allocation mechanism can enable MR-BS to efficiently find out the anchor RS (i.e., the LCA RS) of two subordinate nodes by GCD method, it can benefit the procedure of Mobile Relay Station (MRS) handover. Figure 6.3.22.4.X describes the procedures when MRS handovers between RSs.

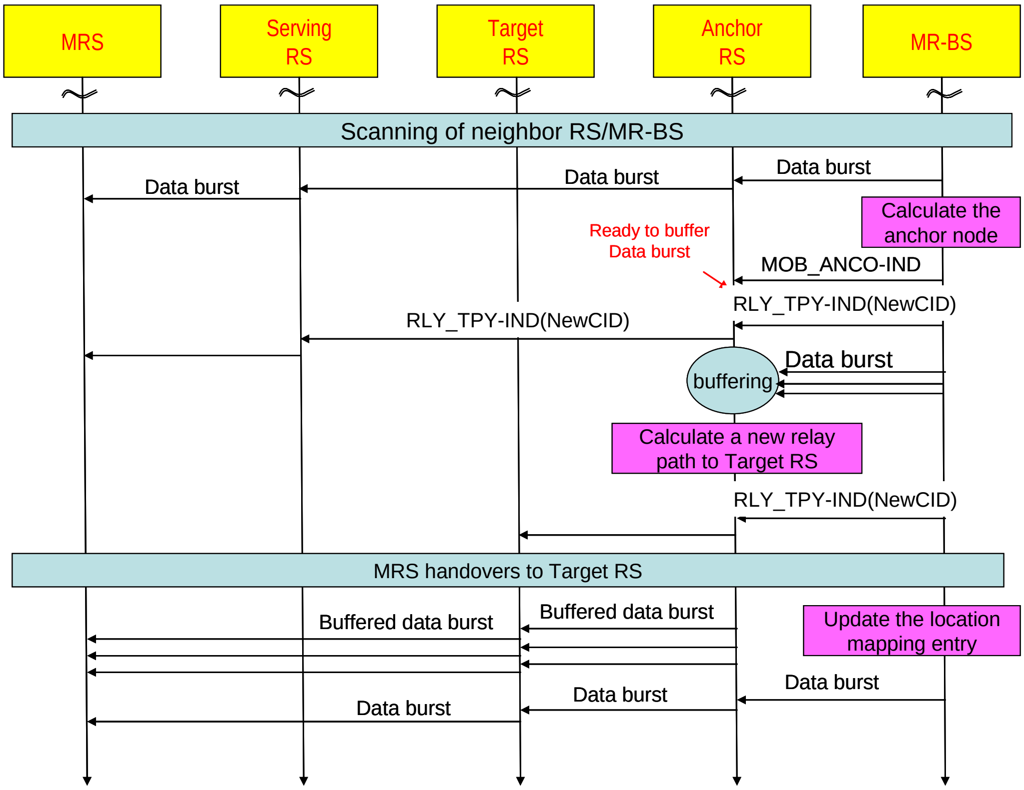

Figure 6.3.22.4.X Message Flow of MRS handover

1. The procedures for the scanning of neighbor RS/MR-BS.
2. Once Target RS has been determined, MR-BS can simply find out the anchor RS (i.e., the LCA RS) between Serving RS and Target RS.
3. MR-BS sends *MOB_ANCO-IND* to indicate the anchor RS, so that the anchor RS can start to buffer the data traffic.
4. MR-BS sends *RLY_TPY-IND* message to pre-allocate a new CID for MRS.
5. Anchor RS calculates a new relay path between itself to the Target RS by prime-based relaying configuration mechanism and then processes the bandwidth reservation for the new path.
6. MRS handovers to Target RS (the detailed handover procedure please refer to Section *6.3.XX.X*).
7. After MRS completes the handover to the Target RS, anchor RS forwards the buffered data traffic to Target RS.
8. MR-BS updates the location mappings entry in accordance with the new CID of MRS. This action makes the sequential data traffic correctly transmitted to the new location of MRS.

The benefits of finding anchor RS are described as below:

- Forwarding data traffic when MRS performs handover can be buffered at anchor RS, so it can release the buffering loads in MR-BS and easily combine with the buffering mechanism for HARQ.
- Since the new relay path can be clearly determined, the bandwidth reservation can only be required along the new relay path between anchor RS and Target RS.

---End text proposal---

3.4 *Message Formats*

---Start text proposal---

[Add the following text into sub-clause of section 6.3.2.3]

- **Relaying mode RS topology indication (*RLY_TPY-IND*) message**

An MR-BS shall transmit a RLY_TPY-IND message for indicating what the suitable preceding RS is and indicating the CID for new RS, and then trigger the network re-entry. A RLY_TPY-IND message may also be transmitted to the selected preceding RS for the notification that a new RS with CID descending from this preceding RS.

Table 6.3.2.3.X—*RLY_TPY-IND* message format

Syntax	Size	Notes
RLY_TPY-IND_Message_format(){	—	—
Management Message Type=xx	8 bits	—
Target_Station_ID	48 bits	—
Preamble_Index/Subchannel Index	8 bits	This parameter defines the OFDMA PHY specific preamble
HO process optimization	8 bits	HO Process Optimization is provided as part of this message is indicative only. HO process requirements may change at time of actual HO. For each Bit location, a value of ‘0’ indicates the associated reentry management messages shall be required, a value of ‘1’ indicates the reentry management message may be omitted. Regardless of the HO Process Optimization TLV settings, the target Station may send unsolicited SBC-RSP and/ or REG-RSP management messages: Bit #0: Omit SBC-REQ/RSP management messages during re-entry processing Bit #1: Omit PKM Authentication phase except TEK phase during current re-entry processing Bit #2: Omit PKM TEK creation phase during re-entry processing Bit #3: Omit REG-REQ/RSP management during current re-entry processing Bit #4: Omit Network Address Acquisition management messages during current re-entry processing Bit #5: Omit Time of Day Acquisition management messages during current reentry processing Bit #6: Omit TFTP management messages during current re-entry processing Bit #7: Full service and operational state transfer or sharing between serving station and target station (ARQ, timers, counters, MAC state machines, etc…)
Connection_ID (CID)	16	This parameter defines a new CID to RS if need
Padding	variable	If needed for alignment to byte boundary
TLV encoded information	variable	—
}	—	—

- ***Mobile Anchor-node Indication (MOB_ANCO-IND) message***

An MR-BS sends MOB_ANCO-IND to indicate the anchor RS of Serving RS and Target RS during MRS handover.

Table 6.3.2.3.XX—*MOB_ANCO-IND* message format

Syntax	Size	Notes
MOB_ANCO-IND_Message_format(){	—	—
Management Message Type=xxx	8 bits	—
HO assistance flags	8 bits	HO assistance flags is provided as part of this message is indicative only. It can enable the indicated anchor node to assist

		handover procedure for turning on/off of HARQ buffering. The bit mappings are defined as: Bit #0: Set for anchor node CID indicated at next field Bit #1: Set for HARQ buffering enable Bit #2~#7: Reserved, default = 0
Anchor node CID	16 bits	—
Padding	variable	If needed for alignment to byte boundary
TLV encoded information	variable	—
}	—	—

4 Summary

In this contribution, we propose a prime-based identification allocation mechanism in the MR network to systematically assign CIDs to RSs. The results of the CID assignment can easily represent the topology of the MR network. Consequently, we further design a prime-based relaying method that fully utilizes the CID allocation results to find relay paths between source and destination nodes inside or outside of the MR network. The proposed prime-based identification allocation mechanism could also decrease the handoff delay since it could quickly locate the anchor RS (i.e., least common ancestor) of serving RS and target RS, so the anchor RS could temporary buffer traffic while the MRS processes the handover, and then redirect traffic to the new RS. Therefore, the proposed prime-based identification allocation mechanism creates the relation between CIDs of RSs and network topology, which could help the MR-BS efficiently manage the MMR network.

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 standard

[6] IEEE 802.16e-2005 standard

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

[8] Y.-Y. Hsu and C.-C. Tseng. Prime DHCP: a prime numbering address allocation mechanism for MANETs. IEEE Communication Letters, 9(8):712–714, Aug 2005.

[9] IEEE C802.16j-06/170, "Connection Identification and Transmission for Relay Support," ITRI contribution

[10] IEEE C80216j-06/167, "RS Network Entry, Topology Establishment and Initialization for IEEE 802.16j," ITRI contribution