國立交通大學

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碩 士 論 文

MS 在 RS 系統的路徑重新選擇機制

MS Path Reselection Mechanism In Multi-Hop Relay System

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中 華 民 國 九 十 七 年 九 月

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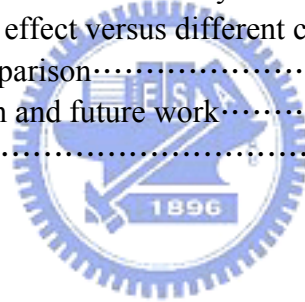
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摘要

　　Wimax (802.16e)是一種可以在城市範圍大小裡能夠提供眾多使用者，以及在這大範圍裡提供高速資料傳輸的技術。雖然有很好的科技來支援這個技術，仍然有許多問題需要去克服，像是如何延長手機電池的待機和使用時間，如何在高速移動中取得高速傳輸的平衡，以及如何提高覆蓋範圍，都是急待解決的問題。然而這些問題都可以藉著導入Relay Station來改善。導入Relay Station有兩個主要的好處：增加訊號覆蓋範圍和提高訊號傳輸量。但是隨著Relay Station數目的增加也使得Handover變的比以前來的更頻繁。而有些不必要的Handover會造成系統的額外負荷以致於訊號傳輸量並沒有提高，並且造成整個系統資源的浪費和效率的降低。在本篇論文中，一個新的路徑選擇機制將被導入Handover中來解決Ping-Pong Effect。經過簡單的模擬後，這個路徑選擇機制不但可以降低Ping-Pong Effect並且提高在Handover之後的SINR改善的量。

MS path reselection mechanism in multi-hop relay system

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Abstract

WiMAX (802.16e) is technically capable of offering city-wide broadband connections to a high number of mobile terminals and provides high speed transmission over large area. The technology has strong industrial support, however a number of challenges remain to be resolved. Major concerns include battery life for mobile terminals, balancing support for high velocity and high data-rate, and increasing area coverage. Relay Station technology is a promising approach to address these challenges. The two major benefits of Relay Station employment are coverage extension and throughput enhancement. As the number of Relay Stations increases, the handover scenarios happen much more often than that of non-RS system. The Ping-Pong effect increases the system loading and may not enhance the system throughput. Some unnecessary handovers also may result in the waste of resource and decreases the efficiency. In this thesis, a path reselection mechanism will be introduced to resolve the Ping-Pong effect and throughput issues. This method is implemented in the simulation whose result shows the Ping-Pong handover reduction and higher SINR improvement after handover by using this proposed path reselection mechanism.

致謝

　　光陰似箭，在職碩士班的這幾年即將畫下句點。在這一段過程中，認識許多好夥伴，其中更有許多是我在研究領域上的貴人，很慶幸有你們的陪伴和幫助，可以讓我順利的畢業，在此我願意將我小小成果分享給大家。

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　　再來，我要感謝跟我一起奮戰的同學，家弘同學，藉由他的督促和照顧，以及提供我許多的幫助，還有，白熊學長也提供了我許多研究上面的建議，並且很有耐心的一一解答我所有的疑惑，由於他們的幫助能讓我順利的完成學業。

　　最後，要感謝我的家人，爸爸、媽媽、太太還有兩個可愛的兒子，全力支持我攻讀碩士班並且讓我沒有後顧之憂，使我可以專心的完成學業。家人在背後的支持，永遠是我動力的泉源。

　　碩士畢業後，我將讓自己的專業知識更豐富、更紮實，也希望能把這幾年在學術研究上的研究方法應用到現行的工作上，使目前的工作更加順利。

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Chapter 1

Introduction

Over the last decade, the number of Internet users has an explosive growth. Currently, most broadband Internet access methods are based on wired communications, such as T1, DSL, and cable-modem technologies. However, there are still a large number of areas where wired infrastructures are difficult to be deployed because of technical or commercial reasons. To provide a broadband wireless access solution, proponents are advocating WiMAX, and IEEE 802.16 standardized wireless technology that supports high throughput broadband connections over a wide range. As standardized, WiMAX employs orthogonal frequency division multiplexing (OFDM) in its physical layer. According to the initial 802.16 standard, WiMAX can provide a single-channel data rate of up to 75 Mbps on both UL and DL. If necessary, service providers can use multiple WiMAX channels for a single transmission to reach a bandwidth of up to 350 Mbps.

In generally, the larger distance between mobile stations (MSs) and base stations (BSs) is, the weaker received quality of signal becomes. In order to provide higher throughput, higher data rate and larger coverage in a wireless communication, the traditional way is to increase the transmitting power of BSs or deploy a lot of BSs. Unfortunately, these methods will produce much interference to other neighbor BSs and surrounding MSs and system performance may not be improved. Thus the relaying technologies [1] are proposed to resolve this problem. The basic concept is to deploy some relay stations (RSs) into BS's cell boundary and RSs forward the received signals from BS and amplify or encode the received signals to its subordinate MSs. By introducing RSs into BS's cell boundary, higher level of Adaptive Modulation and Coding (AMC) would be used to improve the throughput.

Two types of RSs, transparent and non-transparent RSs, are introduced into IEEE 802.16e [2] network to increase the system throughput and coverage area [3]. The former one is to provide only data transmission but not to transmit control signals such as preamble, MAP, and etc. to its subordinate MSs. In this case, a MS is not aware of the existence of the access RS which is transparent to the MS. The later one is to provide both the control signals and data burst for its subordinate MSs. This type of RS can be considered as a BS that could be measured the signal quality by its

subordinate MS. Handover (HO) would happen more often because of the small coverage of RSs and increasing network nodes. It is known that once Handover happens, the corresponding interruption may cause damages to services continuity and reduce the QoS performance. Therefore, how to reduce the occurring Handover frequency and Handover switching latency are the key issues in multi-hop relaying network.

Up to several new schemes had been proposed. [4] A proposal of "Instantaneous Inter-relay Handover" algorithm is to decide which RS would be the best node for accessing. In this algorithm, it classifies RSs into fixed-RS and mobile-RS and also classifies Inter-relay handovers (IRHO) into Inst-IRHO, No-IRHO, and SIR-IRHO. Because Inter-relay handover (IRHO) occurs in MRS or FRS will impact system performance, simulations show that a good path selection in multi-hop relaying network can gain a lot of system capability. A network Coding combined with HO technique is proposed in [5]. With this method, the diversity gain can be acquired between RS and MR-BS to resolve the mobility management with lower outage probability. The hierarchical ID management is also designed in [6]. This management makes MS easy to distinguish intra-cell stations and inter-cell station and the intra-cell handover rate increases to enable lower HO overhead. A novel handover method that reduces inter-cell handover but increases intra-cell handover events is introduced. The purpose of this method is to decrease signaling overhead, latency, and ping-pong effect by the major evaluation metric which including CINR and cell ID information.

In some contribution [7 ~ 15], the problems of MS handover in multi-hop relay network are described. Seven handover cases in an MR network are defined in [7]. These seven cases can be classified into two group, Intra-MR-BS handover and Inter-MR-BS handover. In Inter-MR-BS handover, MS shall conduct 802.16e [2] compliant handover procedures for backward compatibility. MS can sense the handover procedure, so the legacy 802.16e handover mechanism can be reused. [11]

In Intra-MR-BS handover, some issue should be clarified and resolved. New MAC management message needs to be added for MS handover in MR network [7,9,10]. Three handover methods – Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover are discussed in [8,15]. Path selection and reselection issues are the described in [12 ~ 14]. During network entry, select the best path is important in MR network [13] by finding out the most stable

link.

In this thesis, the method to reduce the unnecessary handover (Ping-Pong effect) with MS's fast mobility during handover is proposed. By the simulation result, the unnecessary handover is reduced effectively.

The rest of the thesis is organized as follows. Chapter 2 introduces the Relay Station technique. Chapter 3 provides the Handover Procedure defined in 802.16j and problem statement of MS handover in MR network. In Chapter 4, the simulation setup is addressed and the simulation models are implemented for simulation. The simulation results are discussed in Chapter 5. The conclusion and future study are provided in Chapter 6.

Chapter 2

Introduction of Relay Station Technique

2.1 The Purpose to Use Relay Station

Due to significant loss of signal strength along the propagation path for certain spectrum, the coverage area of IEEE802.16/16e is often limited geographical size. In addition, blocking and random fading frequently result in areas of poor reception or even dead spot within the coverage region. Conventionally, this problem has been addressed by deploying BSs in a denser manner. However, the high cost of BSs and potential aggravation of interference, among others, a relay-based approach can be pursued, wherein low cost relay stations (RSs) are introduced into the network to help extend the range, improve service, and eliminate dead spots, all in a cost-effective fashion.

2.1.1 The Feature to Use Relay Station
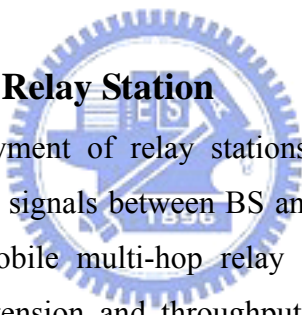
Figure 2.1 is the deployment of relay stations that are installed around the boundary of MR-BS relay the signals between BS and MSs. By specifying the relay stations, the IEEE802.16j mobile multi-hop relay (MMR) provides an attractive solution for the coverage extension and throughput enhancement of IEEE802.16e networks. After RSs are deployed, the Signal to Interference Noise Ratio (SINR) is promoted. Therefore, the higher level of AMC is used to improve the throughput and the MS in the coverage hole or shadow of building can also receive better quality of signals. Coverage extension and throughput enhancement are the two important benefits to the relay station system.

- **Coverage extension**

    Figure 2.2 shows that how relay stations extend cell coverage by transmitting the signal to the MS that may be under the shadow of a building or in the coverage hole.

- **Throughput enhancement**

    Figure 2.3 is the illustration that system has higher throughput over multi-hop paths by deploying the relay stations.
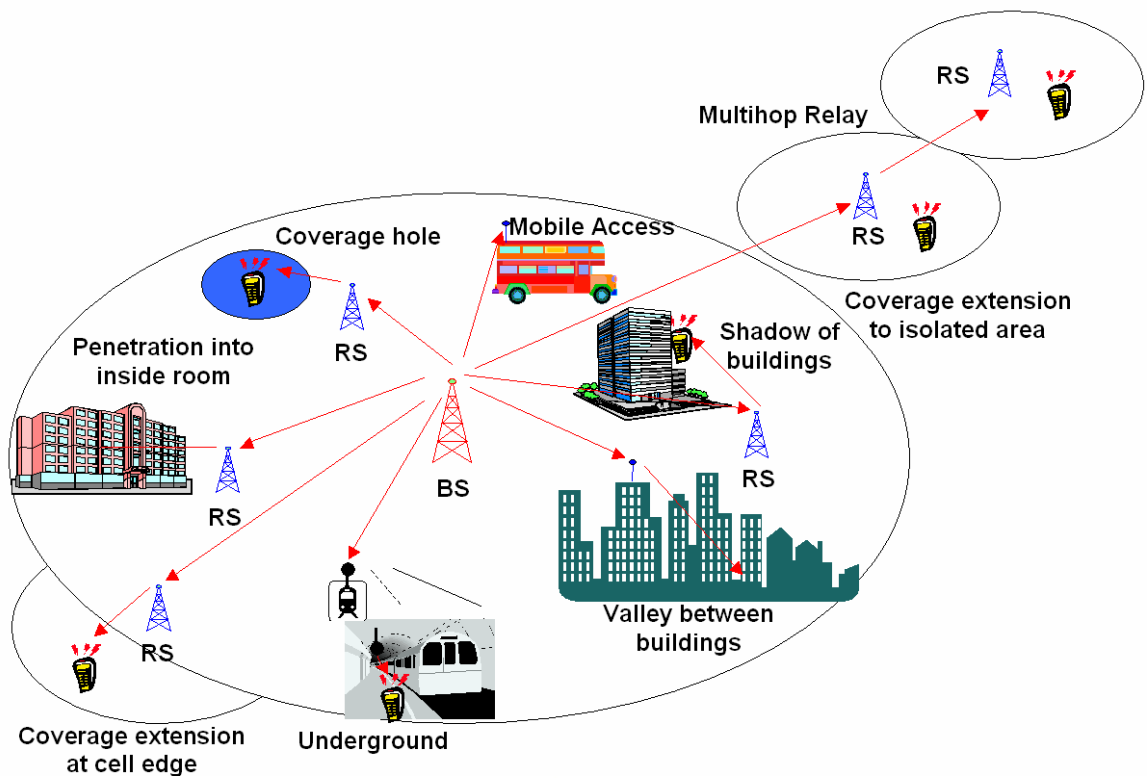
Figure 2-1 Relay Station deployment
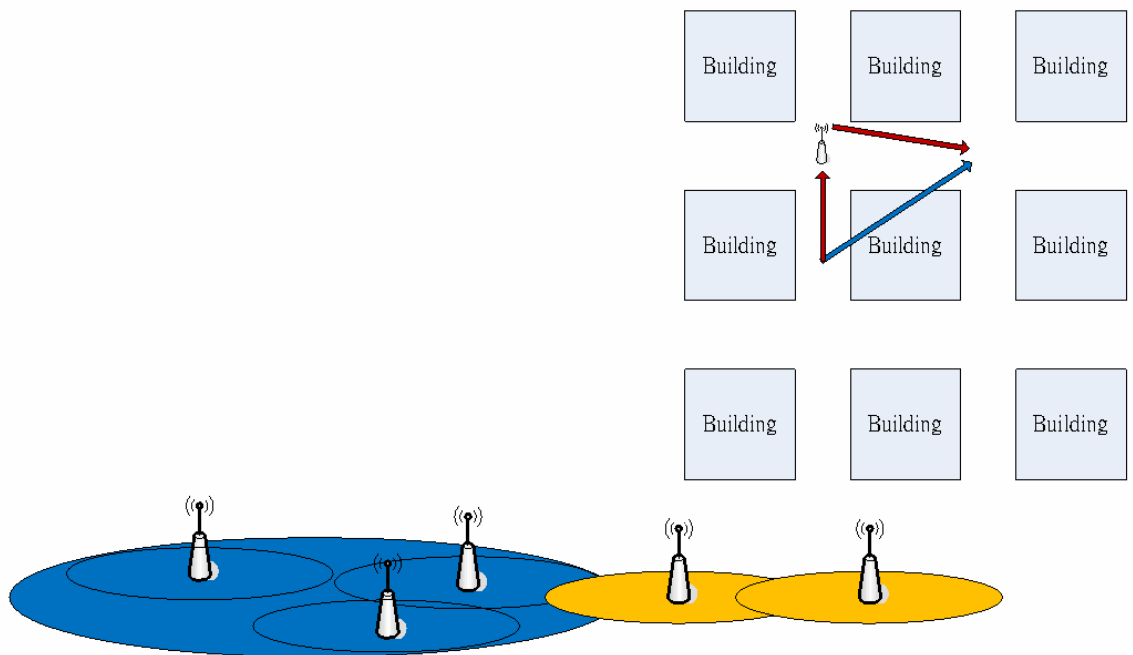
Figure 2-2 Coverage extension

3x2 MIMO

802.16e

802.16j
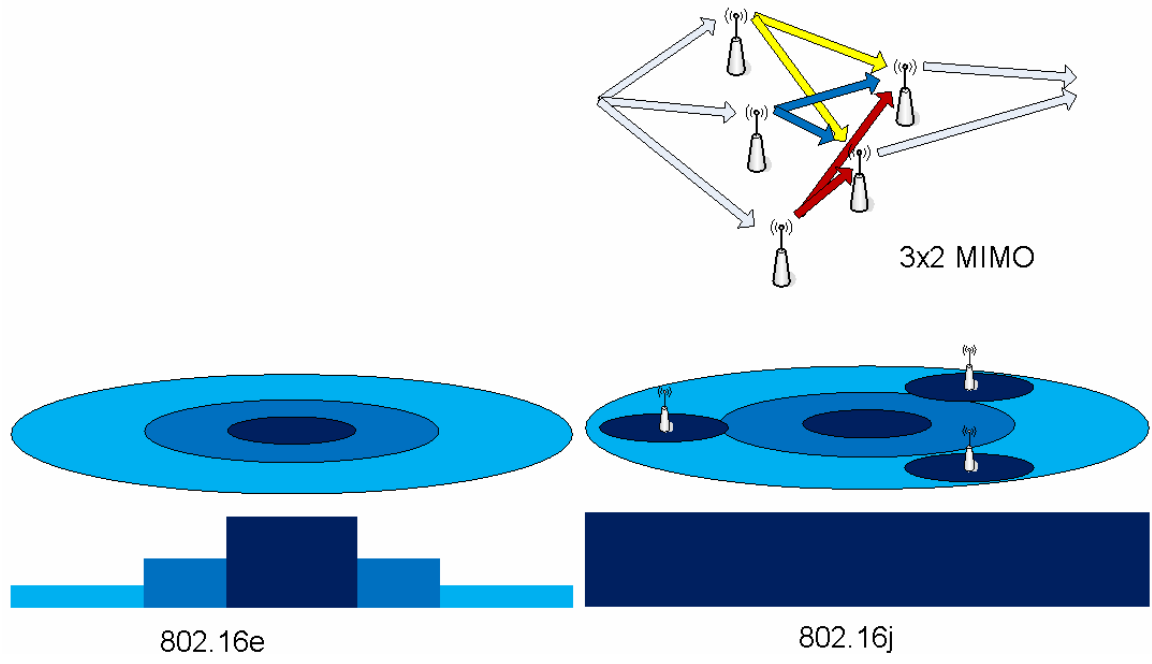
Figure 2-3 Throughput enhancement

Two kinds of relay station are defined in multi-hop relay system. One is transparent RS that transfers only data message but not control message such as preamble and MAP as showed in Figure 2-4. The other one is non-transparent RS that transfers both data and its own preamble and MAP to subordinate MSs in Figure 2-5.
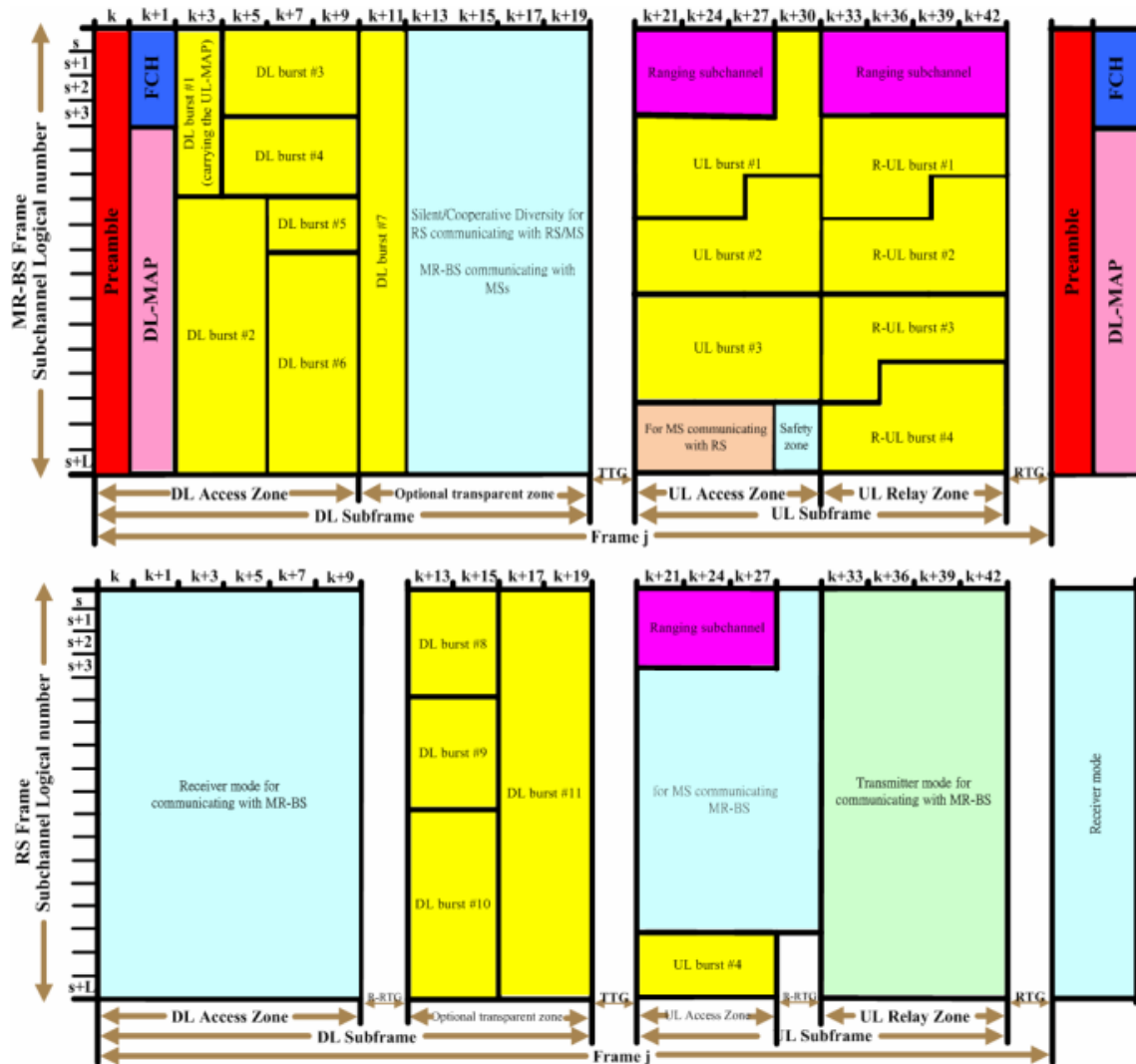
Figure 2-4 Frame structure of transparent RS
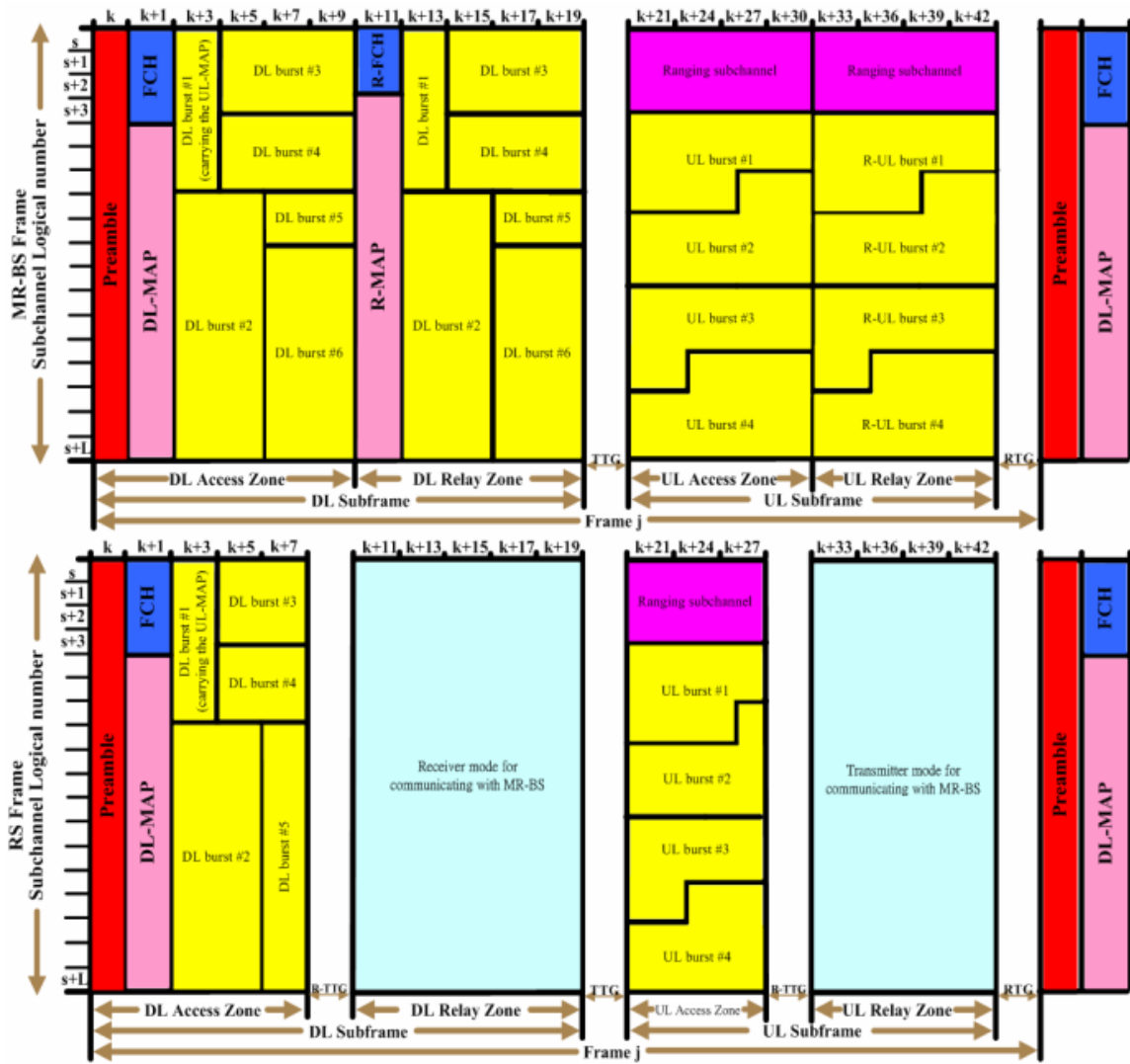
Figure 2-5 Frame structure of non-transparent RS

2.2 Data/control plane of Relay Station

2.2.1 Network entry and initialization

System shall support the applicable procedures for entering and registering a new SS, RS or a new node to the network. All network entry procedures described hereunder through apply only to Point-to-multipoint (PMP) operation and PMP operation with MR support.

The procedure for initialization for an RS is shown in Figure 2-6. As compared with SS network entry, these stages of IP connectivity establishment, time of day establishment, operational parameters transfer, and connections set up are not required, and for all other stages the RS shall have the same behavior as an SS during network entry.

2.2.1.1 MS network entry procedures in transparent RS systems

During the MS network entry procedures in the transparent RS system, MS scans for DL channel and establishes synchronization with the MR-BS, then obtains the transmission parameters from UCD (UL channel descriptor) message. The network entry procedures shall follow the steps as illustrated in Figure 2-7 and are described as follows.

1. MS scans for DL channel and establish synchronization with the MR-BS.

2. The initial ranging process shall begin by MS sending initial-ranging CDMA codes on the UL allocation dedicated for that process. The RS shall monitor ranging channel assigned by the MR-BS.

3. The code may be received by the MR-BS and some RSs near the MS. RSs receiving the code with sufficient signal quality shall transmit a RNG-REQ to the MR-BS with the RS basic CID.

4. RNG-REQ message contains ranging status, code attributes and adjustment information such as frequency, timing and transmission power.

5. When a RS receives multiple codes in a frame, the RS sends MR-BS a RNG-REQ message which contains information of multiple codes which are received with sufficient signal quality.

6. MR-BS compares measured signal information at each station to decide the most appropriate path to communicate with the code originating MS, according to channel measurement information.

2.2.1.2 MS network entry procedures in non-transparent RS systems

During the MS network entry procedures in non-transparent RS systems, MS scans for DL channel and establishes synchronization with the non-transparent RS, then obtains transmission parameters from UCD (UL channel descriptor) message. There are two scheduling mechanism for MS network entry procedures in non-transparent RS systems.

1. The network entry procedures in non-transparent RS with Centralized scheduling as shown in Figure 2-8.
2. The network entry procedures in non-transparent RS with Distributed scheduling as shown in Figure 2-9.

Figure 2-6 RS initialization overview

MR-BS	RS	MS

Time to send the initial
ranging opportunity

← UL-MAP →

Send map containing
Initial Ranging IE

Transmit randomly selected
Initial Ranging code in a
randomly selected Ranging Slot
from available Ranging Region

Receive Ranging Code

← Receive Ranging Code ← CDMA Ranging Code

Receive Ranging Code

Wait for RNG-REQ from RSs

Send RNG-REQ containing adjustment information,
status, ranging code attributes with RS basic CID or
MT-CID.
Status = Continue

Receive RNG-REQ ← RNG-REQ

Compare channel performance and select
the best path. Send RNG-RSP containing
adjustment information, status, ranging
code attributes with initial ranging CID
Status = Continue

RNG-RSP →

Receive RNG-RSP message with
Ranging Code and Ranging Slot
matching sent values. Adjust
Time and Power parameters

Time to send the initial ranging opportunity

Send map containing
Initial Ranging IE

← UL-MAP → UL-MAP →

Receive Ranging Code

← Receive Ranging Code ← CDMA Ranging Code

Receive Ranging Code

Transmit randomly selected
Initial Ranging code in a
randomly selected Ranging Slot
from available Ranging Region

Wait for RNG-REQ from RSs

Send RNG-REQ containing status, ranging
code attributes with RS basic CID or MT-CID.
Status = Success

Receive RNG-REQ ← RNG-REQ

Send RNG-RSP containing status, ranging
code attributes with initial ranging CID
Status = Success

RNG-RSP →

Receive RNG-RSP message with
Ranging Code and Ranging Slot
matching sent values.

Send UL-MAP containing
CDMA_Allocation-IE

UL-MAP → UL-MAP →

Transmit RNG-REQ containing
MS MAC address and continue
with regular Initial network entry

Receive RNG-REQ

← RNG-REQ

Receive RNG-REQ ← RNG-REQ — Forwards the RNG-REQ
to BS with RS basic CID

Identify MS and its connecting RS. Send
RNG-RSP containing management CIDs
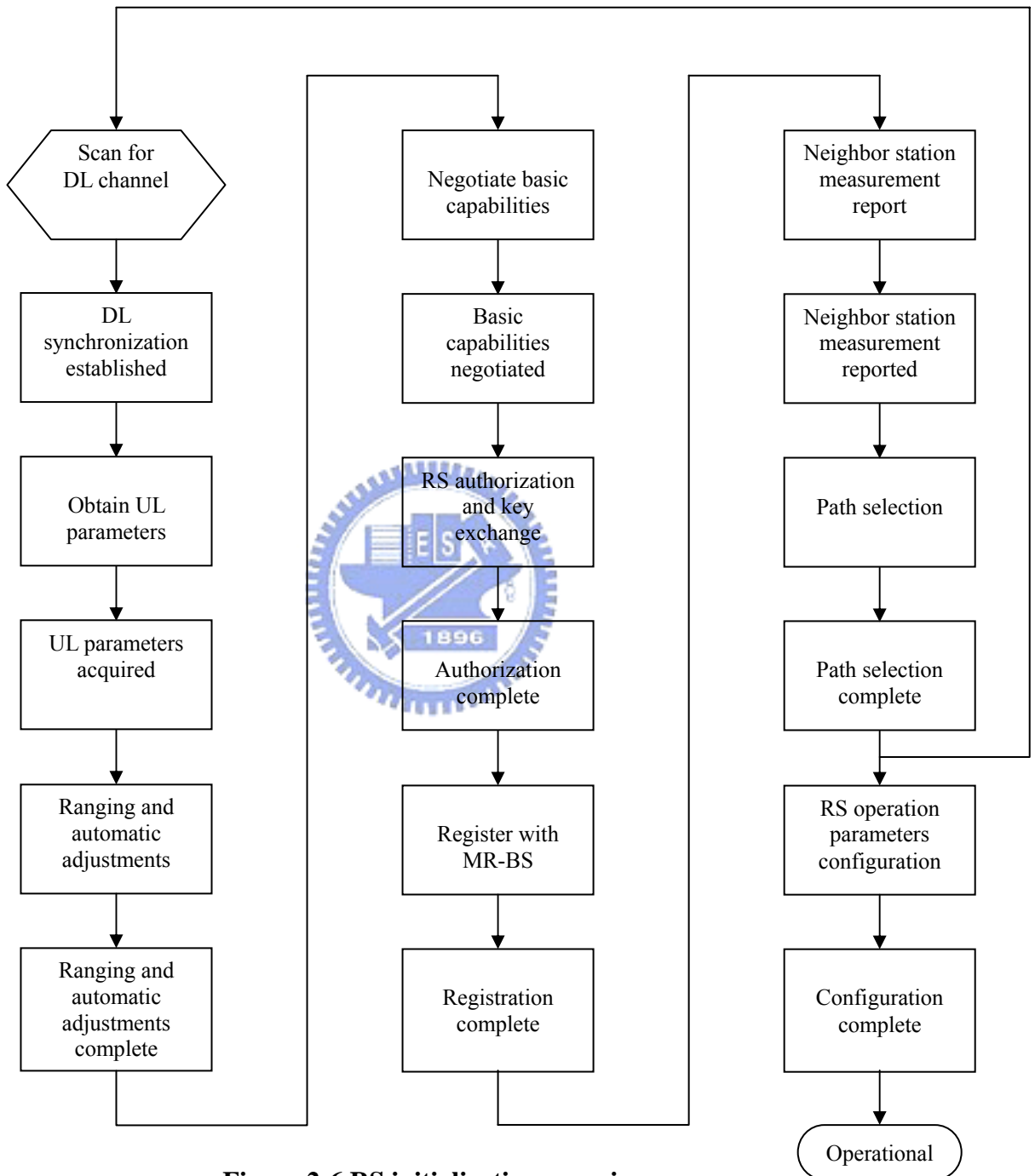with initial ranging CID

RNG-RSP →

Receive RNG-RSP message with
matching MS MAC address

Figure 2-7 Ranging and automatic adjustments procedure in transparent mode

Figure 2-8 Ranging and automatic adjustment procedures in MR mode with centralized scheduling

Figure 2-9 Ranging and automatic adjustment procedures in MR mode with distributed scheduling

2.2.1.3 RS grouping

RS grouping method includes the following characteristics.

● A group of RSs forming a virtual RS group is decided by the MR-BS according to some criteria such as potential interference that they cause to each other. The virtual group may include that MR-BS.

● Each RS is assigned an individual unicast RSID and multicast RSID as the RS group ID. All RSs of the same virtual group have the same multicast RSID. These RSs can be managed individually or as a group by these two separate IDs. These IDs are unique to the associated MR-BS.

● If there is an MR-BS within a virtual RS group, all the RSs of this virtual group shall either transmit the same preamble, FCH, and MAP as that of MR-BS. Otherwise they do not transmit any preamble, FCH or MAP. If there is not an MR-BS within the virtual group and one RS of the virtual group is a non-transparent RS, all other RSs shall either transmit the same preamble, FCH or and MAP as that of the non-transparent RS or all of them do not transmit any preamble, FCH and MAP. These RSs share the radio resources for data burst transmission.

● Removal of an RS from the virtual group : During the normal operation of the RS group, each RS continues to monitor the radio environment. When an RS locates at the boundary of the group coverage area, it detects strong interference form other nearby RS or RS group and it can ask to be removed from the RS group.

● Addition of an RS to an existing group or forming a new group : An Rs at the network entry can have some action.

1. Operate on its own.
2. Form a new group.
3. Join an existing group.

The RS can measure the radio signal from the neighbors and report the measurement to MR-BS regarding the preferred preamble index. The MR-BS would reply by either confirming the preamble index selected by the RS or assigning a different one with the corresponding RS group ID.

● Data forwarding within RS group : For DL, the members of an RS group may be configured to forward traffic data for only specific subordinate terminal nodes.

This may be done on a per-terminal or per-transport connection basis. In this way, by specifying scheduling times, two RSs belonging to the same RS group may transmit to two different MSs at the same time. In addition, transmissions may be scheduled such that multiple RSs in the RS group may transmit to the same MS to exploit macro-diversity. This scheduling may be achieved under a centralized scheduling scheme by keeping an MS list or CID list associated with each RS. Each RS would look for the data bound to its subordinate stations or data coming from the subordinate stations in the UL and forward in the assigned times indicated in the MAP. The list may be updated by the RS_Member_List_Update message. If the RS_Member_List_Update message is not provided by the superordinate RS to the RSs members of the RS group, then all RSs members of the group shall transmit according to the MAPs received, without using the per CID transmission.

● For the UL, diversity combining of the information received by the members of RS group can be performed, or the UL signaling can be designed such that several member RSs may receive data from multiple MS at the same time. This scheduling may be achieved under a centralized scheduling scheme by keeping an MS list or CID list associated with each RS and forwarding those messages in a specified resource unit (time and frequency). When the MS is the same and the resources are the same, it is equivalent to macro-diversity. When the resources are the same but the MSs are different, it is equivalent to parallel transmission occurring at different locations.

● Each time a handover occurs or a new terminal joins an RS group, the list of CIDs for the RSs in the group may be updated.

1. MS network entry procedures

Each RS group member shall monitor the CDMA ranging codes from subordinate nodes. If the group parent is not a member of the RS group, then RS group members shall follow the procedure shown in Figure 2-10. If the group parent is a member of the RS group, then the RS group members other than the parent shall follow the procedure shown in Figure 2-10, and the parent (if not MR-BS) shall follow the procedure shown in Figure 2-11 or 2-12.

2. RS network entry procedures

If the RS is in MS mode of operation, it shall start network entry with the MS network entry procedures as described above. During network entry or normal operation, the MR-BS may configure the RS using RS_Configuration_REQ/RSP messages.

2.2.2 Ranging

A SS or RS shall take the following steps to perform initial ranging:

- After acquiring DL synchronization and UL transmission parameters, the SS/RS shall select one Ranging slot using the random backoff and choose a Ranging Code using a uniform random process. The selected Ranging Code is sent to the BS (as a CDMA code) in the selected Ranging Slot.

- Upon successfully receiving a CDMA ranging code, the BS broadcasts a ranging response message of the received ranging code in the selected ranging slot. The SS/RS uses this response message to adjust its parameters such as time, power and frequency corrections.

- After receiving a ranging response message, the SS/RS shall continue the ranging process as the first entry with ranging codes randomly chosen from the initial ranging domain sent on the periodic ranging region.

- After receiving an initial ranging CDMA code without corrections, the BS shall provide bandwidth allocation for the SS using the CDMA_Allocation_IE to send an RNG-REQ message.

- Initial ranging process is finished after receiving RNG-RSP message with a valid Basic CID. If this RNG-RSP message includes "continue" indication, the ranging process should be continued by the periodic ranging mechanisms.

- The SS should synchronize with the new channel indicated in the RNG-RSP if this message includes an Offset Frequency Adjustment pointing to another channel.

- The timeout for SS/RS to wait for RNG-RSP is defined by T3.

- Using the OFDMA ranging mechanism, the periodic ranging timer is controller by the SS/RS, not the BS.

Only RS should follow the below procedures.

- After receiving UCD message with RS Initial Ranging Code TLV, the RS should use RS Initial Ranging Code not Initial Ranging Code.

- Upon receiving RS Initial Ranging code, the MR-BS may send a RNG-RSP containing "abort" status with preamble indexes of candidate neighbor access stations. The RS shall scan for DL channel of these stations and perform initial ranging.

2.2.2.1 MS periodic ranging and automatic adjustments in transparent RS systems

The detail procedure is shown as Figure 2-10. The periodic ranging process begins be sending a periodic ranging CDMA codes on the UL allocation dedicated for this purpose. After RSs that are near the MS, these RSs shall transmit a RNG-REQ message with the RS basic CID to the serving MR-BS through the relay path. When receiving ranging code, MR-BS shall wait for RNG-REQ message with the same ranging code attribute from its subordinate RSs for T48 timer. If T48 timer is expired, the MR-BS will compare the measured signal information at each access station to decide adjustment information for RNG-RSP.

2.2.2.2 MS periodic ranging and automatic adjustments in non-transparent RS systems

As the periodic ranging process of transparent RS systems, that of non-transparent RS systems also shall send a periodic ranging CDMA ranging code on the UL allocation at the beginning. Two kinds of scheduling method, centralized and distributed scheduling, are introduced for the non-transparent RS systems.

- **Non-Transparent RS with Centralized Scheduling**

Figure 2-11 introduces the ranging and automatic adjustment procedure in non-transparent RS systems with centralized scheduling. RS shall locally send RNG-RSP to MS on the access link when it receives CDMA ranging code from MS. In order to send RNG-RSP to MS on the access link, RS sends a RS BR header to the MR-BS. After receiving the RS BR header, MR-BS will allocate resources for RNG-RSP and indicate to RS with RS_DL_MAP-IE in DL-MAP.

- **Non-Transparent RS with Distributed Scheduling**

Figure 2-12 shows the ranging and automatic adjustment procedure in non-transparent RS systems with distributed scheduling.
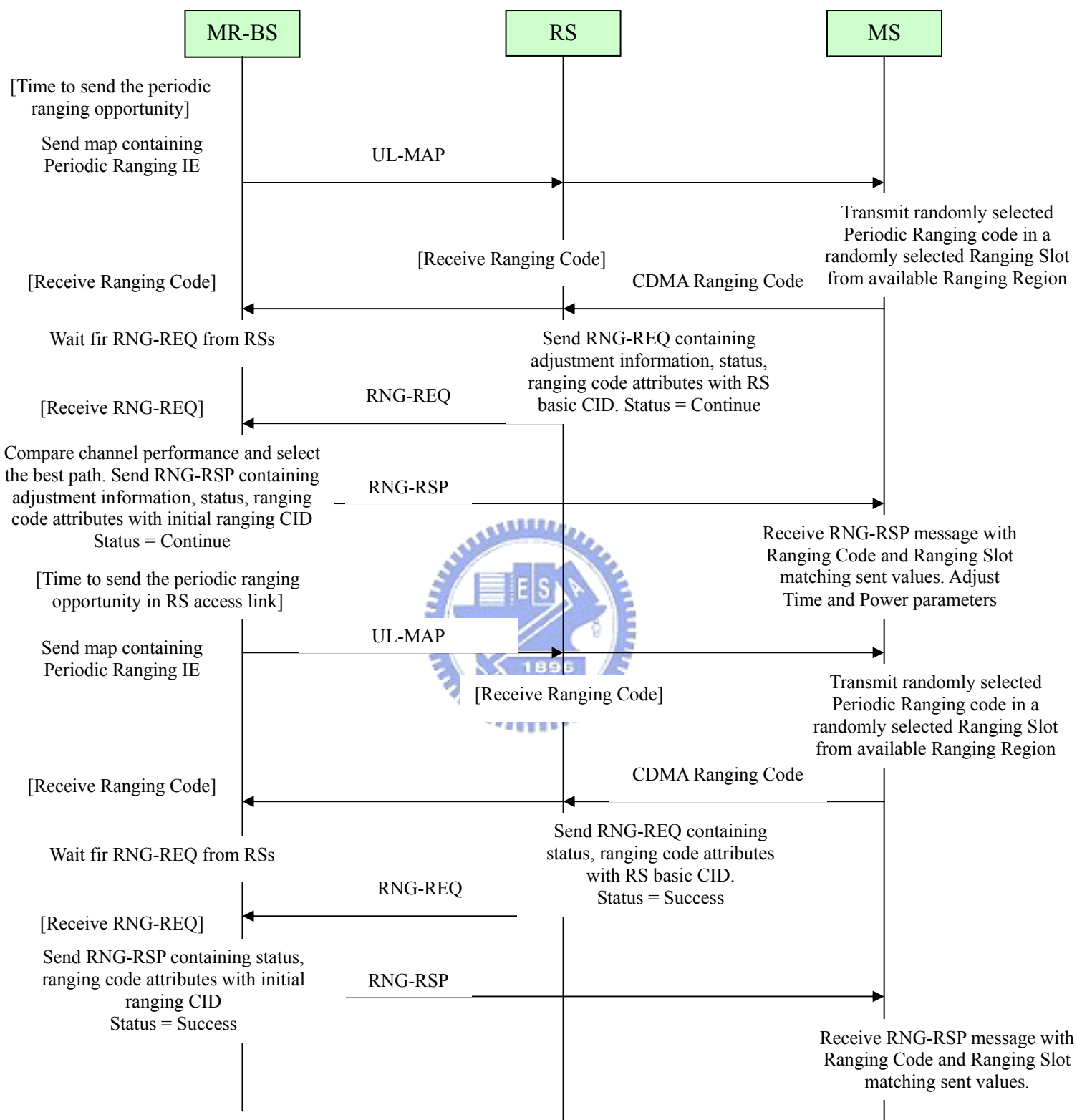
Figure 2-10 Ranging and automatic adjustment procedure in transparent RS system
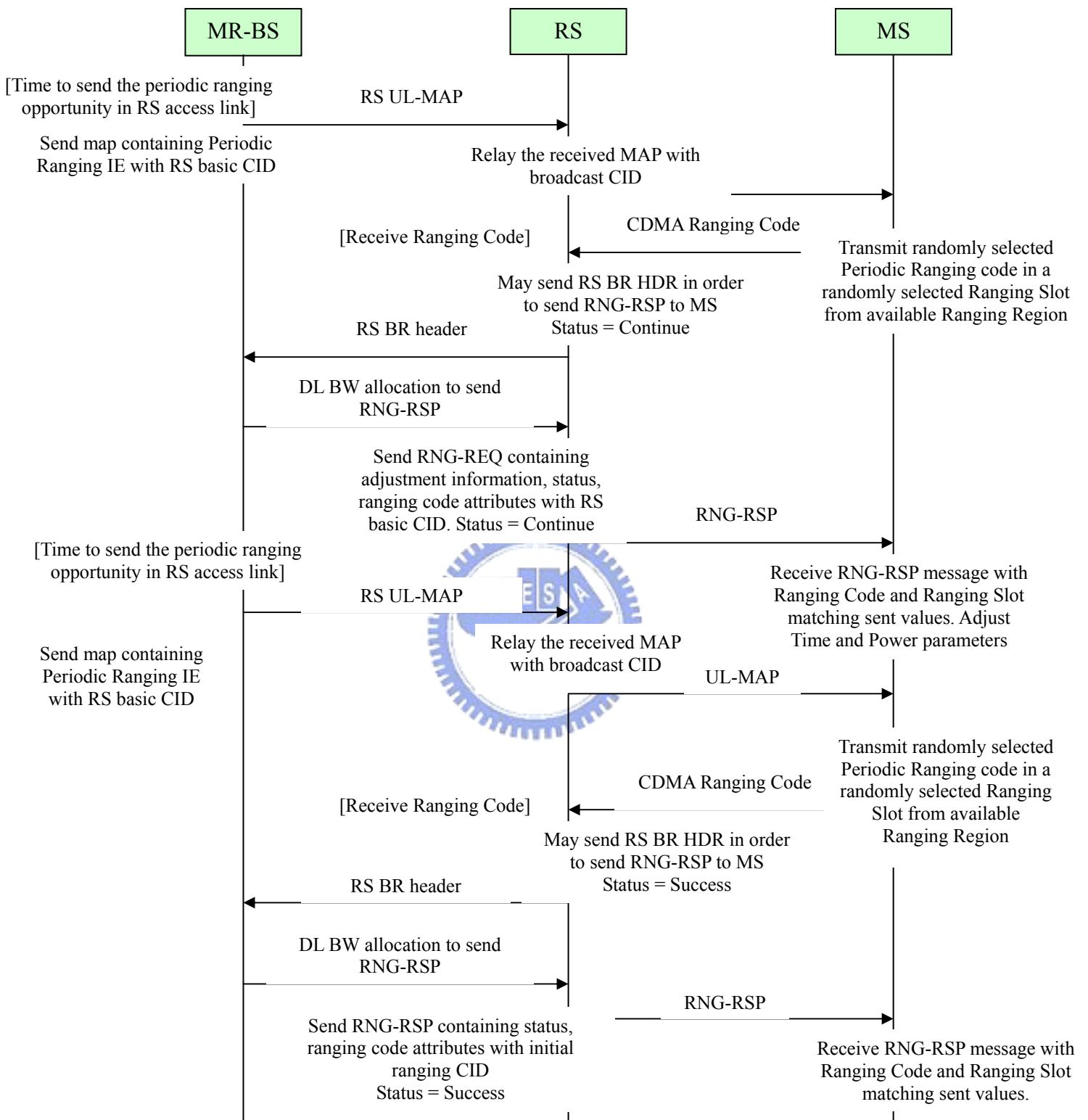
Figure 2-11 Ranging and automatic adjustment procedure in non-transparent RS
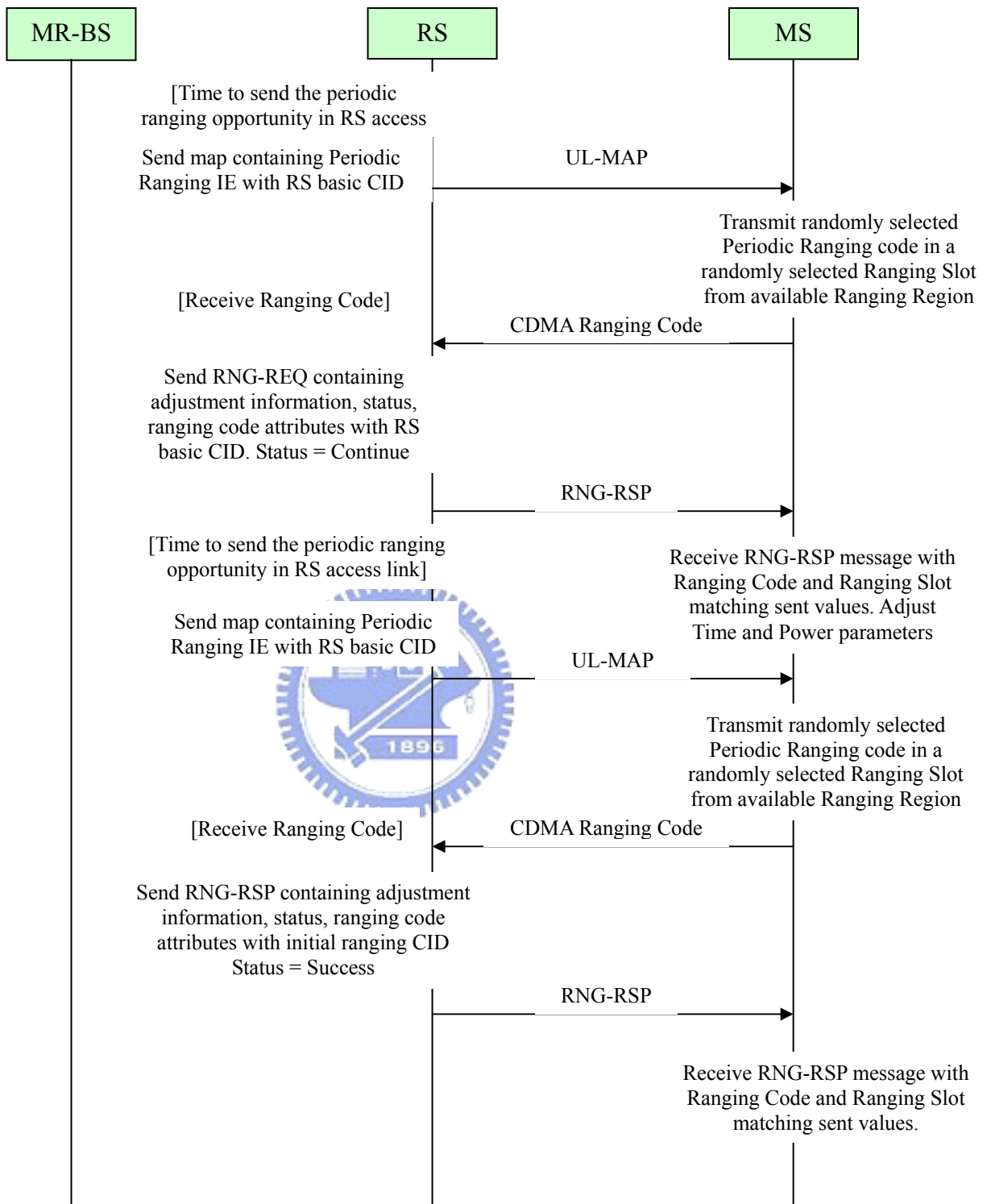
system with centralized scheduling

Figure 2-12 Ranging and automatic adjustment procedure in non-transparent

RS system with distributed scheduling

2.2.3 Relay path management and routing

Based on the topology information obtained from topology discovery or update process, MR-BS makes centralized calculation for the path between MR-BS and an access RS for both UL and DL direction. The path creation is subject to the constraints such as the availability of radio resource, radio quality of the link, load condition of an RS, etc. Either embedded path management or explicit path management may be used.

● **Embedded Path Management for Relay**

When the systematic CID allocation is used, the MR-BS shall update the CID range assigned to its subordinate RSs via the CID_ALLOC-IND message.

● **Explicit Path Management for Relay**

After MR-BS discovers the topology between a newly attached MS or RS and itself, or detects a topology update due to events such as mobility, MR-BS may remove an old path, establish a new path and inform the new path information to all the RSs on the path. When connections are established or removed, MR-BS may distribute the mapping information between the connection and the path to all the RSs on the path. The connection could be a regular connection established for a MS or a connection established for a RS (e.g., basic/primary management CID and tunnel connection).
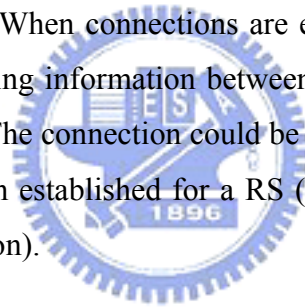
2.2.4 Relay station neighborhood discovery

During the RS neighbor discovery procedure, the potential RS can obtain its neighbor information during PHY synchronization before initial ranging. Therefore, it can send the report to MR-BS after RNG-REQ, SBC-REQ or REG-REQ. Then the RS sends a RS_NBR-MEAS-REP message back to the MR-BS to response the measurement report.

When a RS is newly deployed into a MR network, it can act as a SS/MS and scan the preamble transmitted by the existing stations before network entry. The RS can report its neighbor discovery and measurement results to MR-BS by RS_NBR-MEAS-REP. The neighboring station list may be instructed by MR_NBR-INFO. Because not every RS will transmit its own preamble and the existing RSs in MR network need to perform measurement over the new RS, MR-BS can instruct the RSs to perform complete neighborhood discovery.

There are two methods to carry out neighborhood measurements. One method is to use the repeatable R-amble transmission and monitoring method. After that the measurements can be sent to the MR-BS by the message RS_NBR-MEAS-REP or any other appropriate measurement report messages. The other method for measurement is to use a pre-planned scheme which is described below.

- The MR-BS sends the RS_Config-REQ message to the RSs which will be involved in the neighborhood discovery mechanism, and the message is either sent by the broadcast, multicast or unicast CID for these RSs. The 8 LSB bits of frame number shall be set to instruct the the starting time to the RSs. If the RSs involved in this mechanism are in different MR-cell, each of the Start Frame Number sent by different MR-BSs shall synchronize to the same frame time. The Prefix shall be set "00" and attach the transmit/receive pattern for each iteration.

- The stations follow the instruction to transmit/receive the R-amble at the designated frames in each iteration.

- The RSs report the RSSI or CINR with corresponding amble index by RS_NBR-MEAS-REP to MR-BS.

2.2.5 Interference measurement for MR

Interference prediction is a measurement and reporting method with supported messaging mechanism to estimate the interference level in MR network. In order to predict the interference or SINR of the radio links for different MR- network topology and radio resource reuse pattern, the following prediction method may be considered based on the RSSI reported by RS_NBR-MEAS-REP message.

1. Prediction of the interference plus noise power received by node #i : The interference plus noise may be the summation of (1) the thermal noise plus background interference power received by node #i and (2) the signal power not intended to be received by node #i but transmitted by the same radio resource.

2. Prediction of the received SINR of node #i : The SINR may be the ratio of "the total signal power destined to node #i" to "the interference plus noise power obtained in Step 1".

2.2.6 Messages and data relaying

A non-transparent RS shall broadcast FCH, DCD, UCD, DL-MAP and UL-MAP messages in the DL access zone. In addition, a non-transparent RS shall also broadcast R-FCH, DCD, UCD, and R-MAP messages in the DL relay zone in the case of more than two hops. When the messages are generated by the MR-BS, the MR-BS should send DCD and UCD messages for RS to broadcast on the access link and relay link with RS primary management CID.

Under centralized scheduling, the MR-BS shall generate and send RS-Access-MAP message to RS over RS basic connection once per frame. When RS receives RS-Access-MAP message, RS shall compose FCH and possibly the associated MAPs such as DL/UL-MAP message, Compressed DL/UL-MAP, SUB-DL-UL-MAPs message and HARQ MAP message, etc., based on the RS-Access-MAP message. If the information to compose DL-MAP and UL-MAP messages is not included in RS-Access-MAP, the MR-BS shall send DL-MAP and UL-MAP messages with RS basic CID to the RS directly. In case of more than two hops, the MR-BS shall generate and send RS-RLY-MAP message to RS over RS basic connection once per frame. When RS receives RS-RLY-MAP message, RS shall compose R-FCH and R-MAP based on the RS-RLY-MAP message.

Upon receiving the DCD/UCD message with RS primary CID, as show in Figure 2-13, the RS shall acknowledge the reception of DCD or UCD message over primary management connection by sending an acknowledgment header. The Transaction ID of the ACK header shall be sent to the Configuration Change Count of DCD or UCD message. There shall be one ACK header per message. The RS may retransmit DCD/UCD message if the acknowledgement header is not received at the expiration of T52 timer.

Under centralized scheduling, as shown in Figure 2-14, the RS should request bandwidth on the access link to broadcast the DCD/UCD message with fragmentable broadcast CID.

Under distributed scheduling, the RS shall autonomously broadcast DCD/UCD with fragmentable broadcast CID.
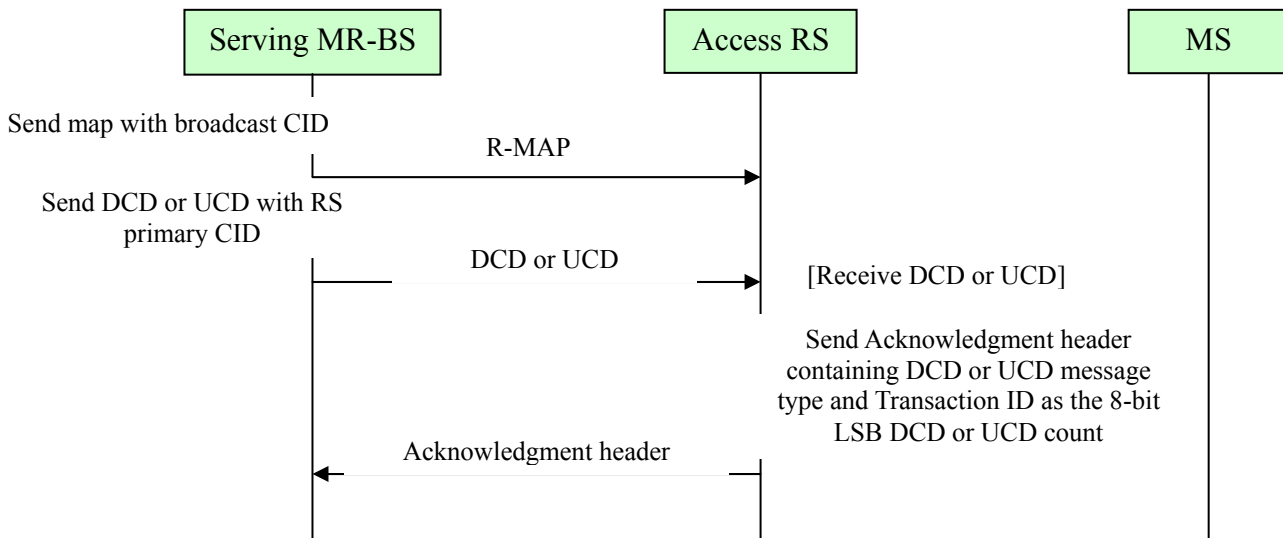
Figure 2-13 Relaying DCD/UCD procedure
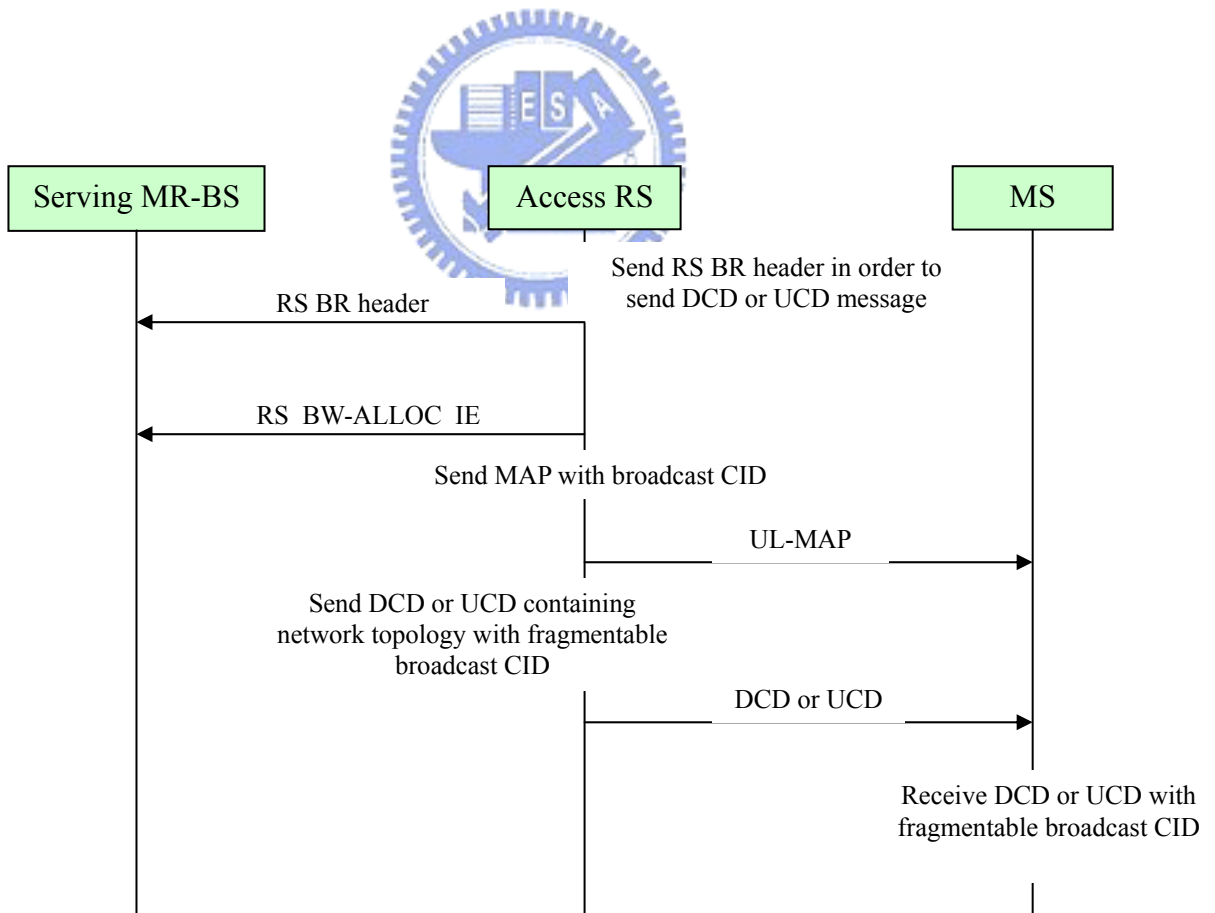
Figure 2-14 DCD/UCD broadcasting with centralized scheduling

2.2.7 RS service end

In MR networks, an RS may end its service and be removed from the networks. During RS service-end process, all subordinate MSs of the RS should be transferred to another RS or MR-BS prior to RS deregistration. An RS shall transmit DREG-REQ to an MR-BS so that it initiates service-end procedure and requests handover of all its subordinate MS's. Upon receiving DREG-REQ, the MR-BS decides whether it allows the RS service-end. If the request is accepted, the MR-BS may transmit DREG-CMD to inform the acceptance and start BS-initiated handover process for the requested MSs. After handover procedures between the MR-BS and its subordinate MSs are completed, the MR-BS informs the RS that handover is completed by transmitting DREG-CMD. Upon receiving DREG-CMD, the RS starts deregistration process.

If the MR-BS rejects the request, the MR-BS informs the RS rejection of the request by transmitting DREG-CMD. Upon receiving DREG-CMD with rejection information, the RS continues normal operation. After REQ-duration expires, the RS retransmits DREG-REQ to the MR-BS.

Chapter 3

Handover Procedure and Problem Statement

In order to realize the handover process, the handover procedure of 802.16e is introduced in the first part. The MAC layer handover procedure overview, association procedure, the detail of each process step, and the fast switch mechanism are described.

In the second part, the handover procedure for relay station system is introduced. This part describes the differences of the MAC layer handover procedure between 802.16e and 802.16j. Next, several MS handover situations are discussed.

In the final part, the problem of MS handover in MR network is discussed and the method to solve the problem is proposed.

3.1 Introduction of MAC layer handover procedure in 802.16e

An MS shall be capable of performing handover using the procedures described in this chapter. There may be some situations to trigger the handover procedure. Two examples are as follows:

- When the MS moves to some locations and affected by the signal fading, interference levels, etc., the MS needs to change the BS to another BS which has better connection in order to provide a higher signal quality.
- When the MS can be served by higher QoS at another BS, the MS changes the access BS to obtain higher QoS.

The handover decision algorithms are discussed in the following chapters.

3.1.1 Network topology acquisition

A BS uses MOB_NBR-ADV message to broadcast its information of the network topology. The MOB_NBR-ADV provides channel information for neighboring BSs normally provided by each BS's own DCD (DL channel descriptor)/UCD (UL channel descriptor) message transmissions. Some BSs may obtain this information from the backbone network.

Figure 3-1 shows that MS scans neighbor BSs and obtains the network topology from the MOB_NBR-ADV broadcasted by the BSs. The MOB_NBR-ADV sent by BS includes the trigger information such as trigger value, trigger averaging duration, trigger type, trigger function, and trigger action. A BS may allocate time intervals to MS for scanning and monitoring the suitability of neighbor BSs as target BS for handover. By using the MOB_SCN-REQ message, an MS may request an allocation of a group of scanning intervals by interleaving the normal operation and recommend a starting frame of the first scanning interval. In the MOB_SCN-REQ message, the MS shall indicate group of neighbor BSs for which only Scanning or Scanning with Association are requested by MS. Upon receiving the MOB_SCN-REQ messages, the serving BS may response the MOB_SCN-RSP message to recommend MS the starting frame. In the MOB_SCN_RSP message, the BS shall indicate this information recommended by BS. After receiving the MOB_SCN-RSP message, the MS shall scan all BSs within the Recommended BS list of the message and then report the scanning result with the MOB_SCN-REP message as conditioned by a specified trigger event.
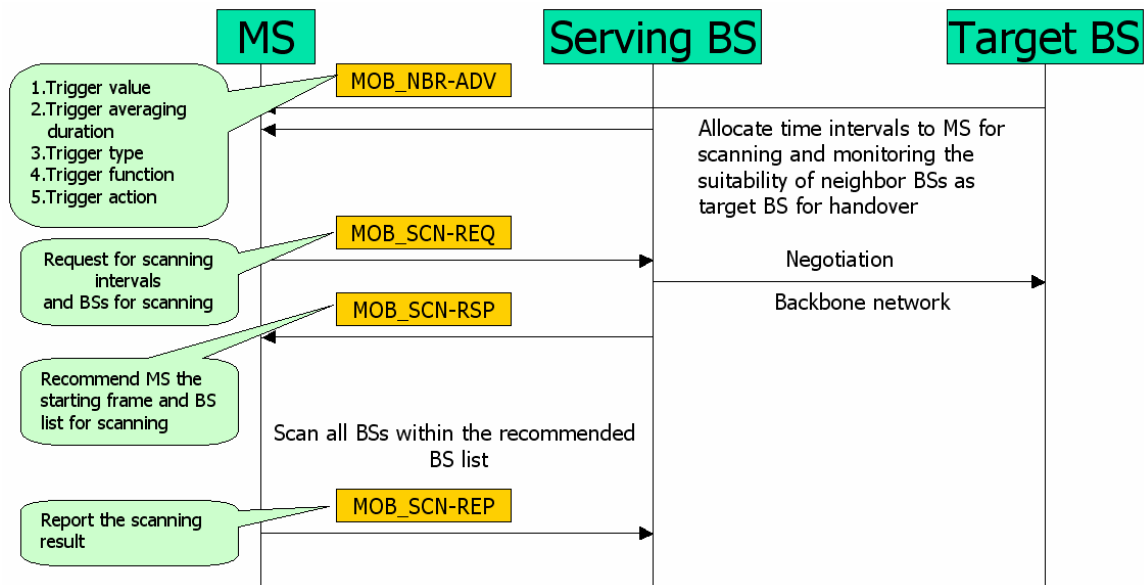
Figure 3-1 MS scanning of neighbor BSs

3.1.2 Association procedure

Association is an optional initial ranging procedure occurring scanning interval with respect to one of the neighbor BSs. There are three levels of association :

● **Association Level 0 : Scan / Association without coordination**

As shown in Figure 3-2, the serving BS and the MS negotiate about the association duration and intervals by using MOB_SCN-REQ and MOB_SCN-RSP with scanning type = 0b001. The serving BS provides periodic intervals where the MS may range neighboring BSs. An MS chooses a ranging code from the initial ranging domain of the target BS and transmits it in the contention-based ranging interval of the target BS.

● **Association Level 1 : Association with coordination**

As shown in Figure 3-3, the serving BS provides association parameters to the MS and coordinates association between the MS and neighboring BSs. The MS may request association with coordination by sending the MOB_SCN-REQ message to the serving BS with scanning type = 0b010. This message may include a list of neighboring BSs that the MS wishes to

perform association with. The serving BS may response to the MS's request by sending the MOB_SCN-RSP message.

- **Association Level 2 : Network assisted association reporting**

  As shown in Figure 3-4, the MS may request the association with network assisted association reporting by sending the MOB_SCN-REQ message to the serving BS with scanning type = 0b011. The list of neighboring BSs that the MS wants to perform association with may be included in this message. After receiving this message, the serving BS will coordinate the association procedure with the requested neighboring BSs in a process similar to the association level 1. In this association type, the MS only transmits the CDMA ranging code and does not wait for RNG-RSP message.
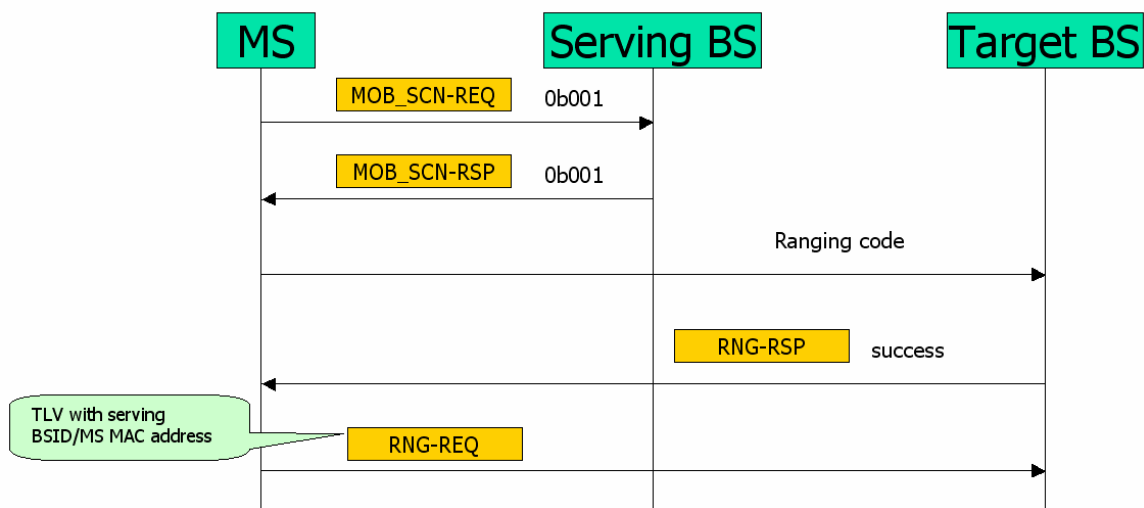

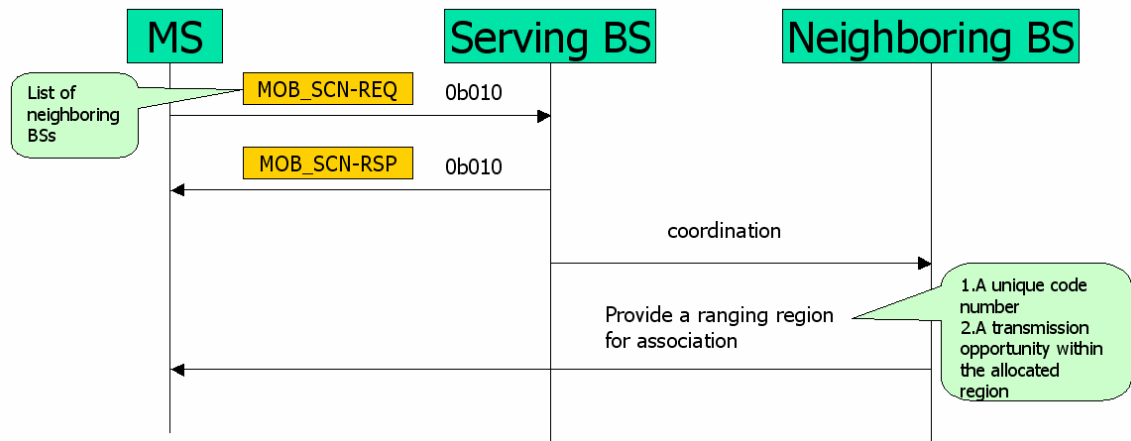**Figure 3-2 Association Level 0 – Scan / Association without coordinate**

Figure 3-3 Association Level 1 – Association with coordination
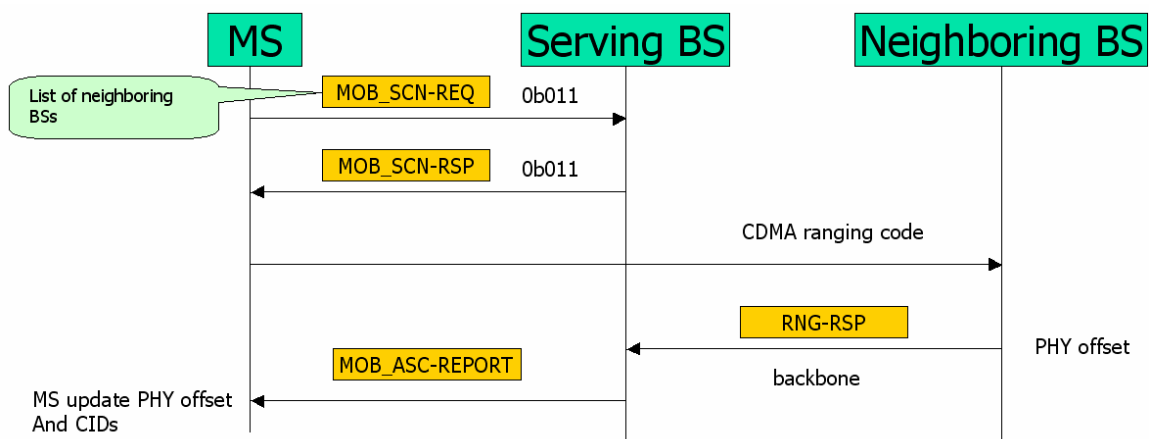
Figure 3-4 Association Level 2 – Network Assisted Association Reporting

3.1.3 Handover Process

This section defines the handover process in which an MS migrates from the air-interface provided by one BS to the air-interface provided by another BS. The following stages are included in the handover process.

- **Cell reselection** – Figure 3-5 shows this stage that MS may use the MOB_NBR-ADV message to obtain the neighbor BS information and make a request to schedule scanning intervals or sleep intervals to scan, and possibly range, neighbor BSs for the purpose of evaluating MS interest in handover to a potential target BS.

- **Handover decision and initiation** – An Handover Process begins for an MS to handover from the serving to a target BS by a decision made by either the MS or the serving BS. The Handover decision may be initiated by MOB_MSHO-REQ from MS or MOB_BSHO-REQ from BS. MS may evaluate the possible target BS and report it to BS. MS may decide to handover to a different BS that may or may not be in the MOB_BSHO-RSP message. Figure 3-6 shows this handover stage.

Figure 3-5 Cell reselection
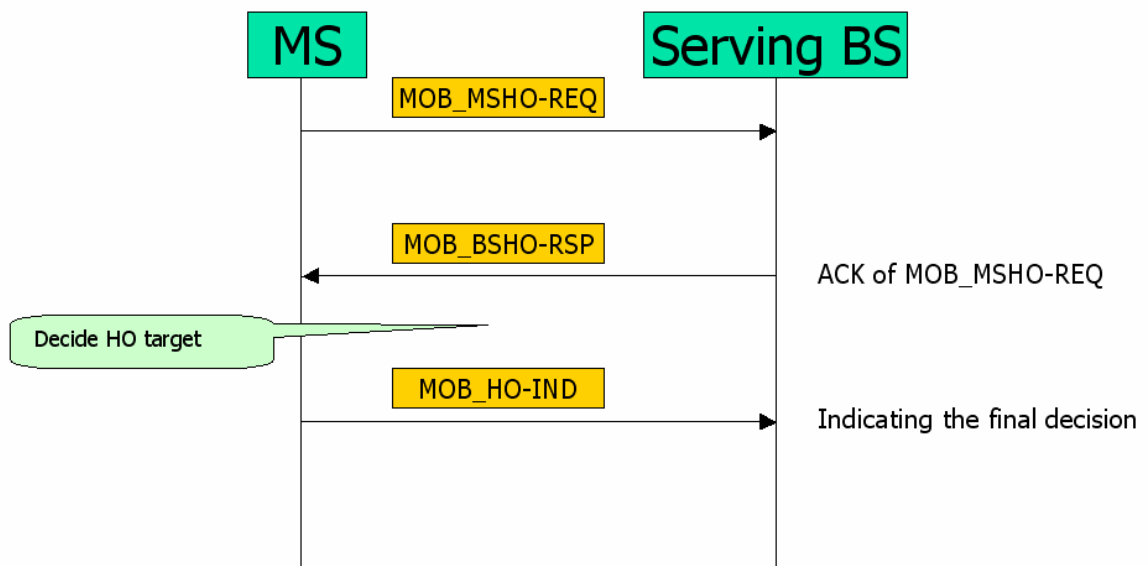
Figure 3-6 Handover Decision and Initiation

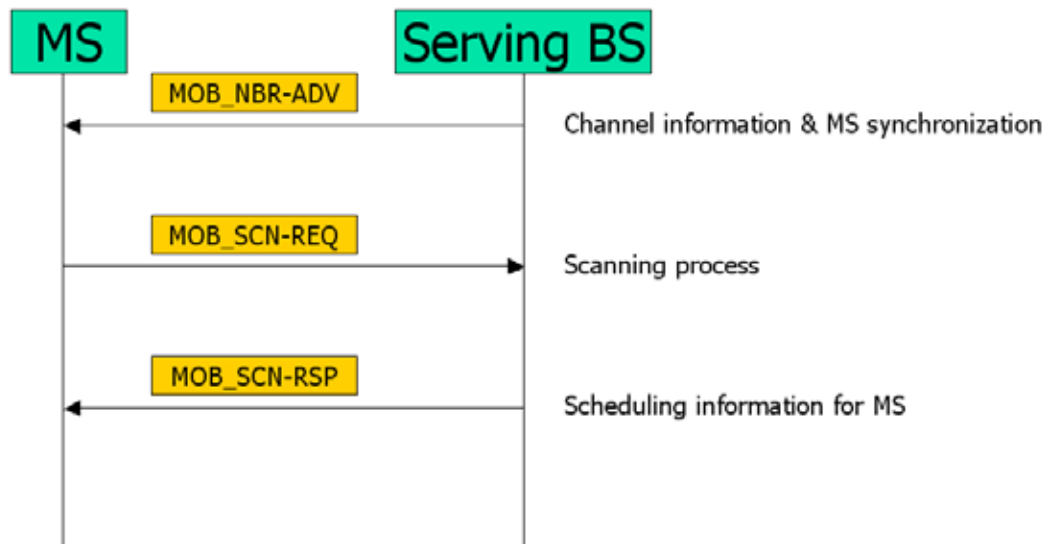● **Network Re-entry – Synchronization and Ranging** – The MS shall synchronize to the DL transmissions of the Target BS and obtain DL and UL transmission parameters. If the MS had previously received a MOB_NBR-ADV message including Target BSID, Physical Frequency, DCD and UCD, this stage may be shortened. If the Target BS had previously received Handover notification from the Serving BS over the backbone network, then the Target BS may allocate one or more non-contention-based initial ranging opportunities. Upon receiving MS RNG-REQ message including serving BSID, the target BS may send a request to serving BS for the information of MS over the backbone network and the serving BS may respond. As indicated in the Handover Optimization TLV (type/length/value) settings, the target BS may select to use MS service and operational information obtained over the backbone network to build and send unsolicited SBC-RSP (SS basic capability response) or REG-RSP (registration response) management messages to update MS operational information, or to include this information into TLV items in the RNG-RSP. The detail flow is as shown in Figure 3-7.
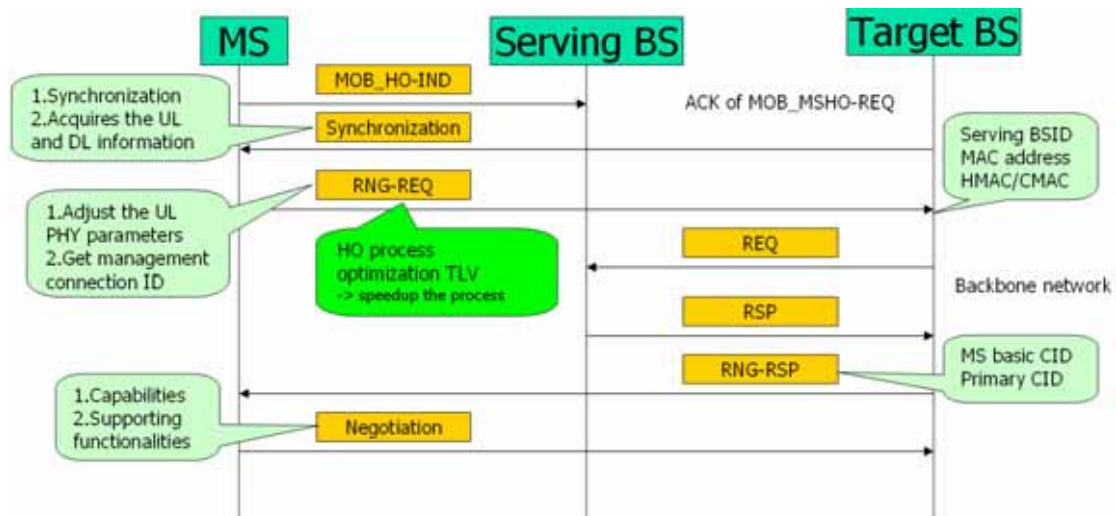
Figure 3-7 Network Re-entry – Synchronization and Ranging

- **Handover cancellation** – Although an MS or BS has initiated a Handover procedure by using either MOB_MSHO-REQ or MOB_BSHO-REQ message, the MS may cancel the handover procedure at any time by sending the MOB_HO-IND message with HO_IND_type = 0b01.

- **Termination with the serving BS** – After the Handover request and response handshake has completed, the MS may begin the actual handover process. At the some stages described above during the handover process, the MS terminates service with the original serving BS by sending a MOB_HO-IND message with the HO_IND_type value indicating which serving to be released.

3.2 Introduction of MAC layer handover procedure in 802.16j

The MS's MAC layer handover procedure in 802.16j is the same as the procedure defined in 802.16e. In this section, the MAC layer handover procedure related to relay station shall be discussed. There may be some situations to trigger the handover procedure. Two examples are as follows:

- When the MS moves to some locations and affected by the signal fading, interference levels, etc., the MS needs to change the RS/BS to another RS/BS which has better connection in order to provide a higher signal quality.

- When the MS can be serviced with higher QoS at another RS/BS, the MS changes the access RS/BS to obtain higher QoS

3.2.1 Network topology acquisition

The MR-BS and the RS shall broadcast the MOB_NBR-ADV message including the information about the infrastructure stations and this information may be obtained over the backbone network or over the relay links. Each non-transparent RS can broadcast its MOB_NBR-ADV message for its service area. For transparent RS, the MOB_NBR-ADV message shall be broadcasted by the MR-BS. There are two methods to generate the MOB_NBR-ADV message for an RS.

- Broadcast the MOB_NBR-ADV message without modifying the neighbor list of the MR_NBR-INFO message received from the MR-BS.

- Customize and compose a MOB_NBR-ADV message by utilizing the information present in the MR_NBR-INFO message as well as any additional information that the RS itself may have obtained, for instance, by scanning and measurement.

3.2.1.1 MS scanning of neighbor BSs

MR-BS shall control MS scanning of neighbor BSs in MR network. An RS relays MOB_SCN-REQ, MOB_SCN-RSP and MOB_SCN-REP messages between an MS and the MR-BS in centralized scheduling or distributed scheduling. The procedure of MS scanning is shown as Figure 3-8.
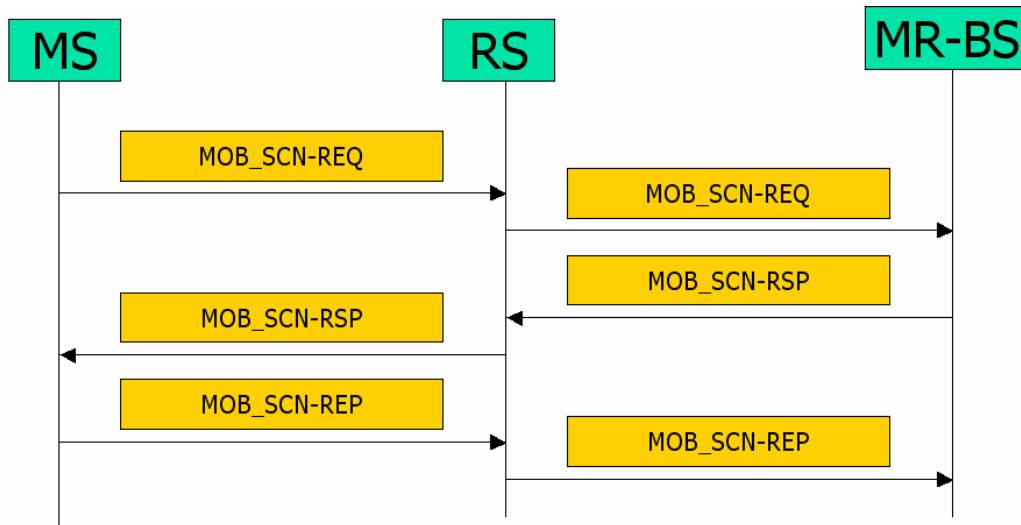
Figure 3-8 MS scanning of neighbor BSs

3.2.2 Association procedure in an MR network

3.2.2.1 Association parameter acquisition

If the serving MR-BS decides to recommend the MS to scan its neighbor stations with association level 1 or 2 in a MR system with distributed scheduling, it obtain the association parameters available from the MS's neighbor stations before send the MOB_SCN-RSP message. If this neighbor stations is located in a different MR-cells from the MS, the MS's serving MR-BS shall send a message via the backbone network to the MR-BS of the neighbor stations to obtain the association parameters. In the case that this neighbor station is an RS, its serving MR-BS must forward an MR_ASC-REQ message to the RS to request to forward its association parameters using MR_ASC-RSP message. This procedure is shown as Figure 3-9.

If the neighbor station is an RS in the same MR-cells as the MS, the serving MR-BS shall directly request the RS for the association parameters using MR_ASC-REQ message.

If the allocated association level is 1 or 2, the MR_ASC-RSP message sent by the RS should include the association parameters such as Rendezvous time, CDMA code, and Transmission opportunity offset.

After receiving these association parameters, the MR-BS should forward this information to the MS via MOB_SCN-RSP if these information satisfy the MS's association requirements.
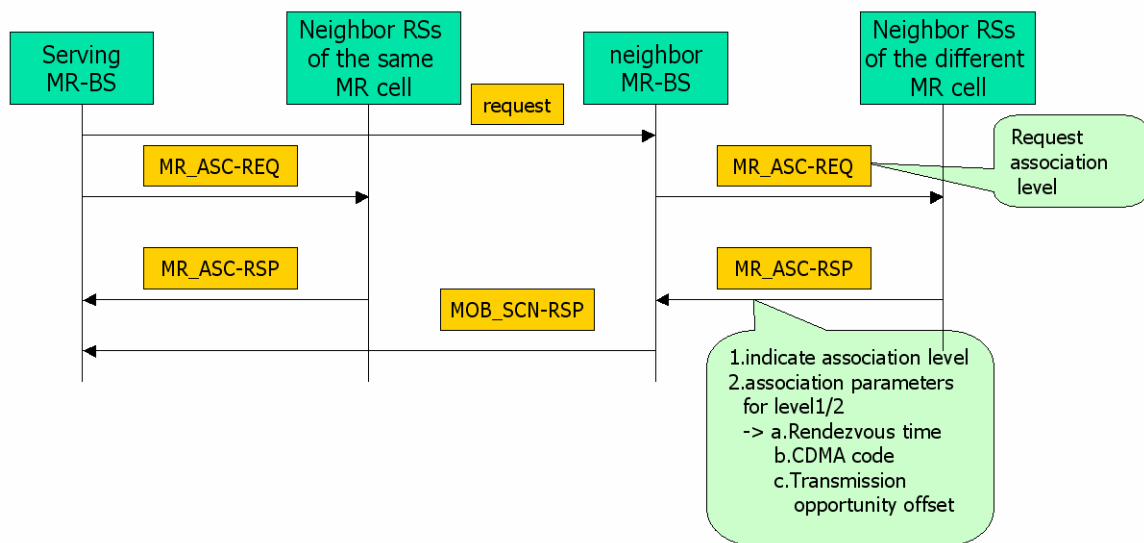
Figure 3-9 Association parameter acquisition for different MR-cell

3.2.2.2 Association level 0 and 1

As shown in Figure 3-10, upon successfully receiving a ranging code from a scanning MS, the neighbor station shall provide an UL allocation for the MS to transmit an RNG-REQ message including Serving BS ID and MS MAC address. If the neighbor station is an RS, is shall forward the RNG-REQ message to its MR-BS and the MR-Bs shall respond an RNG-RSP message for the RS to forward to the MS.

3.2.2.3 Association level 2

While using association level 2, the scanning MS shall transmit a CDMA ranging code to the neighbor station. The neighbor station shall send the RNG-RSP message to its serving MR-BS instead of the MS. If the MR-BS is not the serving MR-BS of the MS, it shall send the RNG-RSP message to the MS's serving MR-BS via the backbone network. The MS's MR-Bs shall generate a single MOB_ASC-REP message from all RNG-RSP information of all of the MS's neighbor station. This message flow is shown as Figure 3-11.

Figure 3-10 Association level 0 and 1
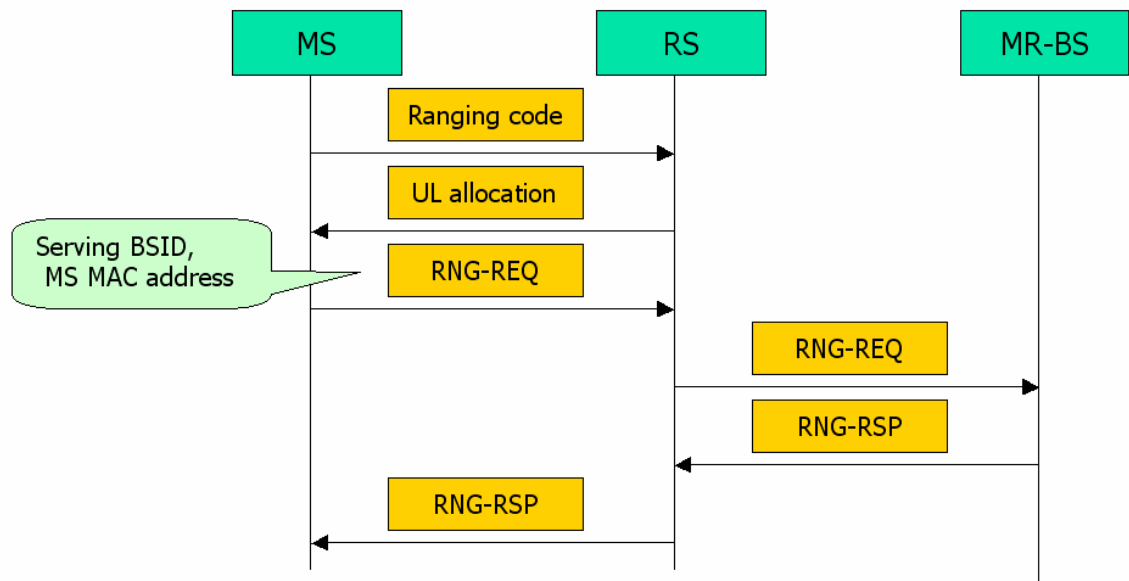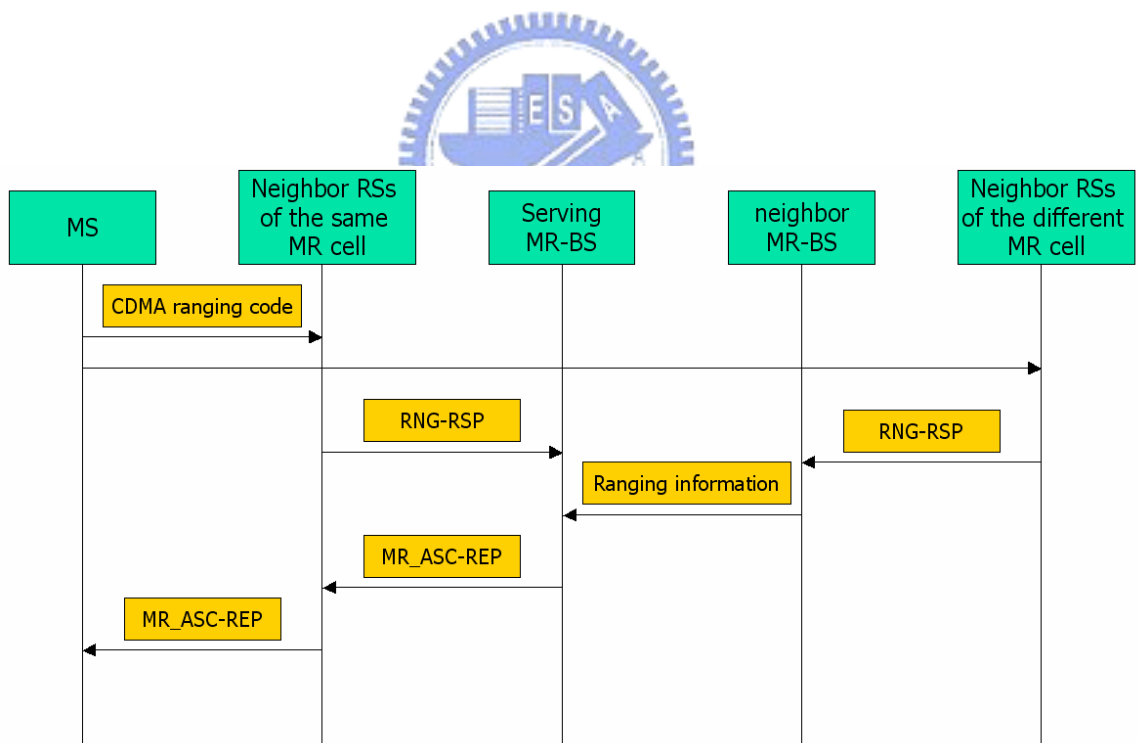

Figure 3-11 Association level 2

3.2.3 Handover process

The handover process of 802.16j is almost the same as that of 802.16e for the MS part so in this section, the difference between these two handover process is discussed.

MR-BS shall control handover process in centralized control MR network. An RS shall relay the handover associated messages between the MS and the MR-BS both in centralized scheduling and distributed scheduling.

3.2.4 Mobile relay station handover

In this section, the Relay Station Handover process is defined as Figure 3-12. An relay station migrates from the air-interface provided by one access station to the air-interface by another access station. This RS handover process includes the same stages as those defined for the MS handover process with the following additional stages.

- **Path selection.** Enable the target MR-BS to indicate a path reselection. The target MR-BS may skip this stage if the bit#0 in RS HO optimization TLV of RNG-RSP is set.

- **RS operational parameter configuration.** Enable the target MR-BS to reconfigure RS operational parameters. If the bit #1 in RS HO optimization TLV of RNG-RSP is set, the target MR-BS may skip this stage.

- **Transport/tunnel connection re-establishment.** Enable the target MR-BS to re-establish transport/tunnel connection for an RS. If the bit #2 in RS HO optimization TLV of RNG-RSP is set, the target MR-BS may skip this stage.

- **MS CID update.** Re-establish the connection between the child MSs and the target MR-BS if the MS handover procedure is not invoked between the MS and the target MR-BS. If the MS handover procedure is invoked, this stage shall be skipped. MS CID update is only needed if the MS CID based data forwarding scheme is used and a CID of a child MS collides with the CID of another MS served by the target MR-BS. Then the MR-BS informs the RS to perform the MS handover procedure regarding the new CIDs if its child MSs.
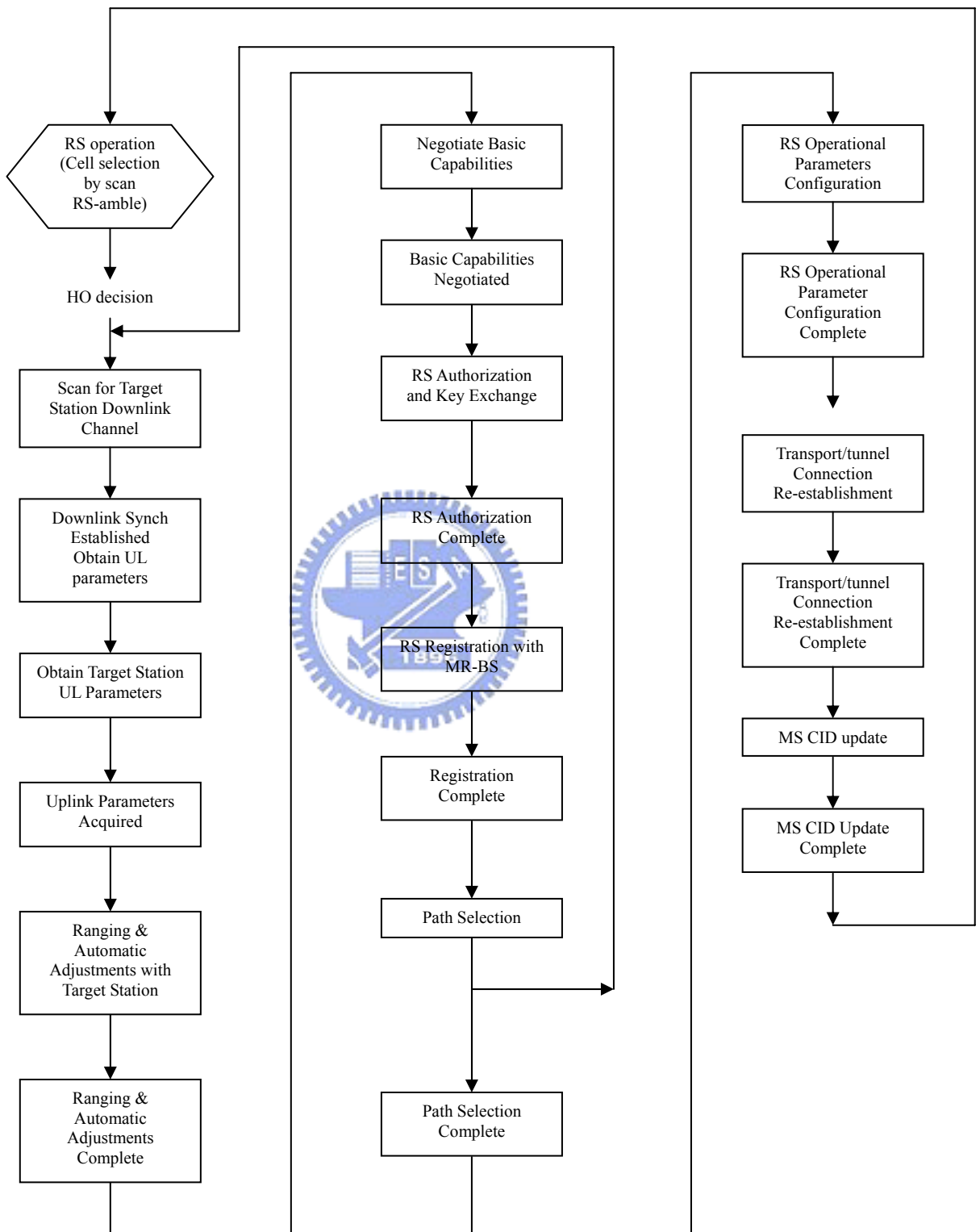
Figure 3-12 Relay Station Handover Procedure

3.2.5 MS handover procedure involving RS

An MS, connected through an RS or MR-BS, shall follow the same handover procedure as described for an MS handover procedure.

3.2.5.1 MS movement among access stations with different preamble/FCH/MAP

The Relay Station shall relay Handover management messages between MS and MR-BS. If the serving MR-Bs knows that the MS handovers to a new access station or the Resource retain timer expires, and the MS's old access station is an RS under the control of the MR-BS, the MR-BS shall send the MS_INFO-DEL message to the RS discard MS context information. After receiving the MS_INFO-DEL message, the RS shall respond the MS_DEL-ACK message to the MR-BS. This flow is shown as Figure 3-13.
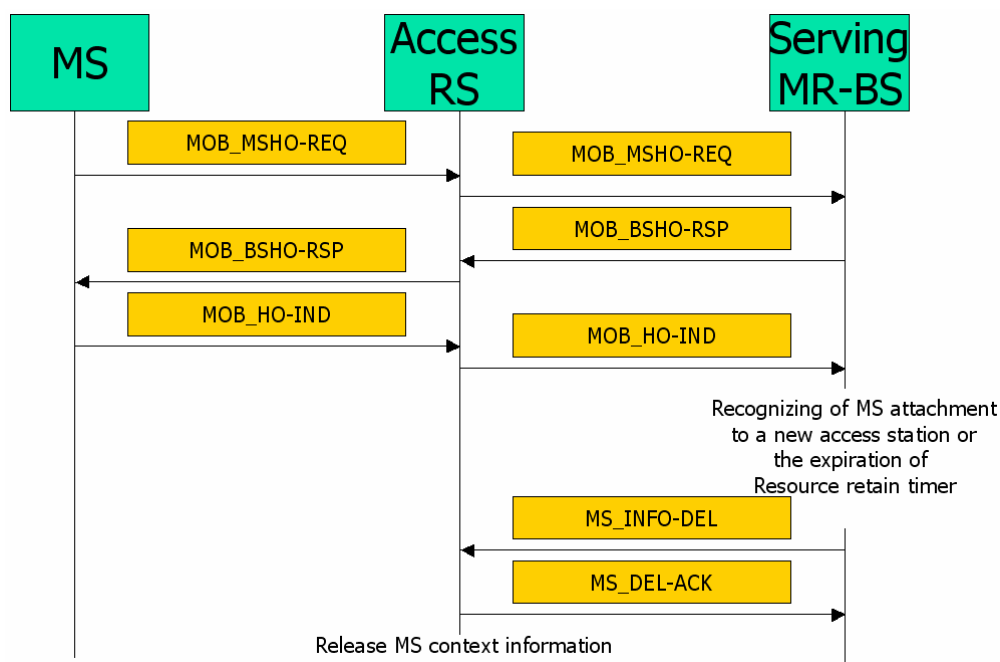
Figure 3-13 Handover procedure involving RS with centralized HO control from MR-BS

3.2.5.2 MS movement among access stations with same preamble/FCH/MAP

In this case that all access stations use the same preamble/FCH/MAP like RS virtual group, the MS is not aware of the handover. Therefore, the RS and MR-BS shall assist MS movement among stations using the same preamble/FCH/MAP by performing measurement of the MS signal quality. The stations sharing the same

preamble/FCH/MAP shall measure the signal quality (RSSI, CINR) and the Timing Adjust (TA) for each active MS served by these stations to support MS mobility among these stations. All RSs shall use the MOB_RSSCN-REP message to provide the MR-BS the report metrics (RSSI, CINR, and TA) for each active MS. There are two reporting modes supported by RSs described as the following sections. Upon receiving the report, the MR-BS shall select the target RS and use RNG-RSP to adjust the timing and the power level of the MS to finish the handover procedure.

- **Mode 1**

  In this mode, only the access RS shall automatically report its measurement result to MR-BS in an event-triggered or periodic way. The MR-BS shall send the MOB_RSSCN-RSP message to request all or part of RSs of the same RS virtual group to report their measurement result for a specific MS. For event-triggered reporting, if the power, CINR, or timing requirement for the specific MS is not satisfied, the access RS shall report it to the MR-BS. For periodic reporting, the access shall send the measurement result by the MOB_RSSCN-REP message every REP_INT interval.

- **Mode 2**

  In this mode, all RSs including access RS and non-access RSs in the same RS virtual group shall automatically the measurement result by the MOB_RSSCN-REP message to the MR-BS in an event-triggered or periodic way. The condition of the event-triggered and periodic way is the same as that of mode 1.

3.2.6 MS MAC handover procedure in a MR network

The 802.16j MAC handover procedure [3] need to enable an 802.16e compliant MS to handover seamlessly in a MR network following the MAC handover procedure defined in P802.16Rev2/D2 [2]. Figure 3-14 depicts the seven handover cases that are classified into two type.

- Intra-MR-BS handover: The MR-BS sends the RNG_RSP message to the given MS for power level, timing advance adjustment to MS adapt to the target access station.

  1. Case 1: The current access station is a MR-BS and the target access

station is a RS in the same MR cell.

2. Case 2: The current access station is a RS and the target station is a serving MR-BS. The current station and the target station are in the same MR cell.

3. Case 3: The current access station is a RS and the target access station is another RS in the same MR cell.

There is an issue that will be discussed in the following sections.

■ Path reselection issue: The proposed method is to reduce the unnecessary handover (Ping-Pong Effect) with MS's fast mobility.

● Inter-MR-BS handover: The legacy 802.16e handover procedures can be reused in these cases.

1. Case 4: The current access station is a MR-BS and the target access station is another MR-BS in the different MR cell.

2. Case 5: The current access station is a MR-BS and the target access station is a RS in a different MR cell.

3. Case 6: The current access station is a RS and the target access station is a MR-BS in a different MR cell.

4. Case 7: The current access station is a RS and the target access station is another RS in a different MR cell.

In this type of handover, the conclusion is as below.

■ MS shall conduct 802.16e compliant handover procedures for backward compatibility.

■ MS can sense the handover procedure, so the legacy 802.16e handover mechanism can be reused.
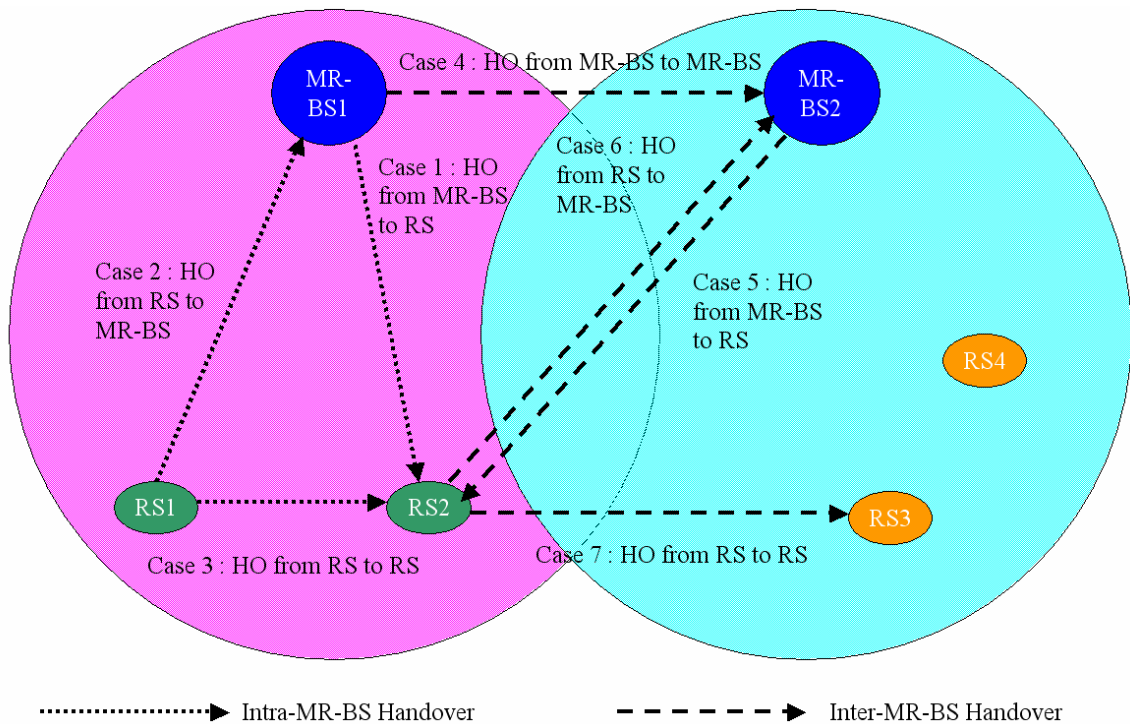
Figure 3-14 Seven handover cases in a MR network

3.2.7 Problem statement in Intra-MR-BS handover

For the Intra-MR-BS handover, some situations that are different from that of legacy 802.16e need to be clarified.

1. MS cannot sense the transparent RS.

   In 802.16e, MS can sense the downlink signal quality of the BS and can trigger the handover procedure if the signal quality is too low. In 802.16j, because MS is not aware of the transparent RS, no downlink signal can be used to trigger the intra-MR-BS handover as legacy 802.16e.

2. MS cannot distinguish the difference between the serving access station and the target access station.

   In 802.16e, each BS has its own preamble, so MS can easily identify the different signals of the serving access station and target access station. In 802.16j, only MR-BS can send its own preamble and the transparent RS just relays the signals between the MR-BS and the MS, so MS can not distinguish the signal difference between the MR-BS and the RS.

3. MS cannot sense the intra-MR_BS handover procedure.

In 802.16e, the MS can trigger the handover procedure and participate in the whole handover procedure. In 802.16j, the MS cannot participate the handover procedure and the whole handover procedure can only be fulfilled and managed at the MR-BS.

4. Ping-Pong Effect may occur very often.

The cell coverage of RS is much smaller than that of legacy 802.16e BS so the frequency of MS handover scenarios in a MR networks is increased significantly. The unnecessary handover between two specific access stations is called Ping-Pong effect. The proposed method to reduce this Ping-Pong effect is discussed in the following section.

3.2.8 Proposed path reselection mechanism

In [18 ~19], a novel metric, called ERRI, which indicates the effectiveness of radio resource of a link used to transmit data is proposed to find out the best path while MS network entry. A performance analysis for a wireless relay system that counts asymmetric relay path as one of the possible transmission paths is discussed in [20]. The above discussions only propose the mechanism to select the best path for MS network entry. In this thesis, there is a proposed method to decide the right time to handover to reduce the unnecessary handover, called Ping-Pong Effect.

Figure 3-15 shows the handover situation that may occur very often in a MR network if the MS's mobility is too fast. The MR-BS need to take care of the whole handover procedure and decide whether the MS handover to the target access station or not. In this case, if the MS moves into RS's coverage with a high mobility, the MR-BS will trigger the MS to handover to the RS and then handover MS from the RS back to the MR-BS. This handover scenario is the topic that needs to discuss here. To avoid this situation that causes the increasing system loading, a new path reselection mechanism is proposed.
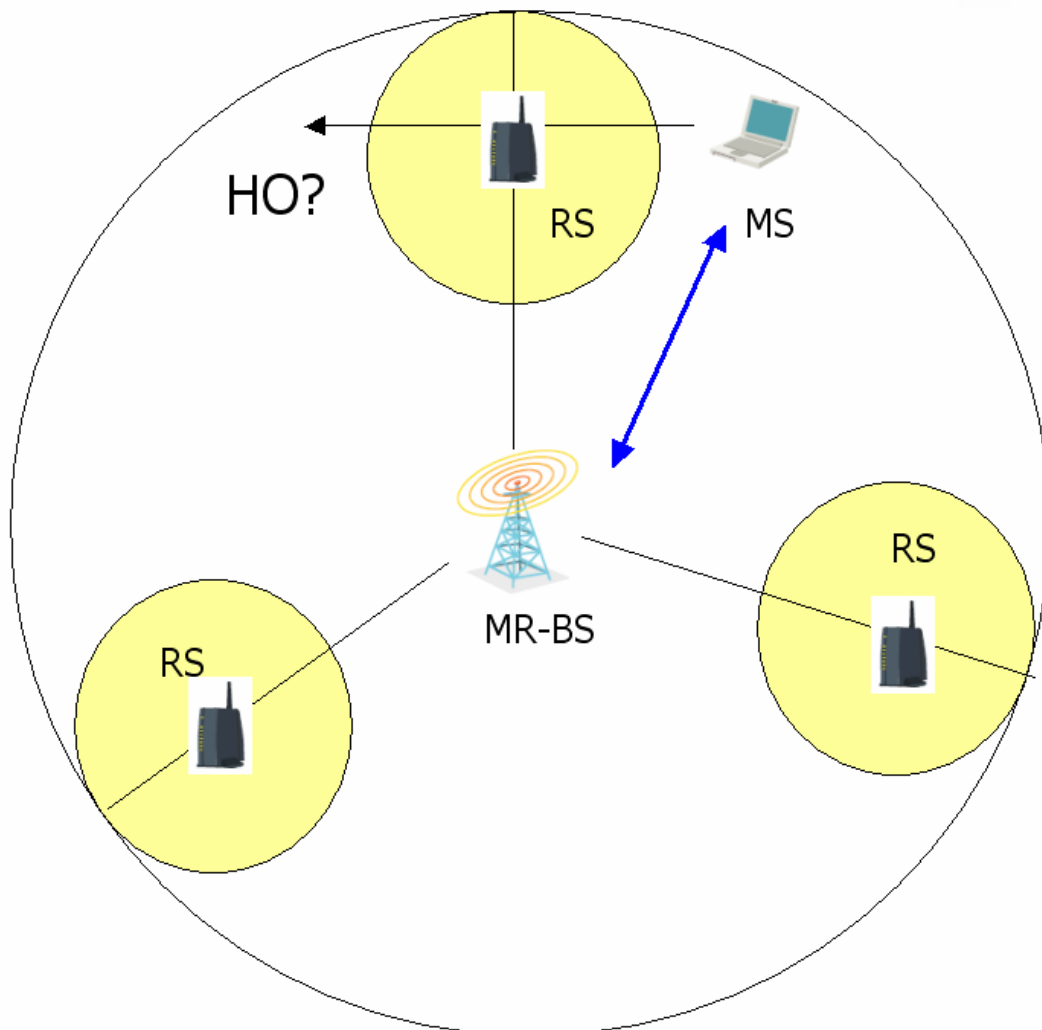
Figure 3-15 The handover situation in a MR network

3.2.8.1 Target access station reselection metric

Some criteria are considered in this proposed path reselection mechanism.

- SINR: calculate and deliberate on the link quality of single path.

  Two factors need to be discussed in this criterion.

  1. SINR Strength: $SINR_{Target} > SINR_{Current}$

  2. SINR Stability:

- Hot Counts: calculate and take care of the link quality of multi path.

  1. SINR Strength: $SINR_{RS\text{-}MS} > SINR_{MRBS\text{-}MS} + SINR_{margin}$

  2. AMC: $1/AMC_{MRBS\text{-}RS} + 1/AMC_{RS\text{-}MS} < 1/AMC_{MRBS\text{-}MS}$

The details of simulation models setting and the simulation result will be described in the following chapters.

Chapter 4

Simulation Models Setup

In this chapter, the system level for handover simulation is described. The simulation parameters and several handover modes are explained in the following sections. The simulation parameters such as link budget, path loss, and shadow fading are referred to [16,17]. Several handover models also implemented in this simulation are described in this chapter.

4.1 The simulation environment setup

Due to the interference is a key factor that affects the system performance in the real system, a inter-cell interferences environment for the multi-hop relay system shall be set up in simulation. The deployment of stations like base station, relay station, and mobile station is described in this section. The SINR calculation and measurement based on the link budget, path loss, and shadow fading are explained in this section.

4.1.1 Base station deployment

As shown in Figure 4-1, there are nineteen base stations deployed in this simulation. The radius of each base station is set to 500 meters. Due to simulate the handover scenario, the implement of wrap around base station is necessary. After the base station deployment, three sectors are set for each base station as shown in Figure 4-2.

The setting of the antenna pattern is referred to 3GPP's model [?] as following.

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right], \text{ where } -180 \leq \theta \leq 180$$

For 3 sector $120°$ antenna pattern, θ_{3dB} is $70°$, A_m is 20 dB, and bore-sight gain is 3 dB, where θ_{3dB} is the Azimuth rad in which the antenna pattern gain is 3dB loss, A_m is maximum loss compared with maximum antenna pattern gain, and bore-sight gain is the maximum antenna pattern gain on the direction of antenna bore-sight. In AAS

zone, 15° beamwidth is adopted, and θ_{3dB} is 8.75° , A_m is 29 dB, and bore-sight gain is 12 dB. Figures 4-1 and 4-2 are the location setting and sector configuration of each base station.
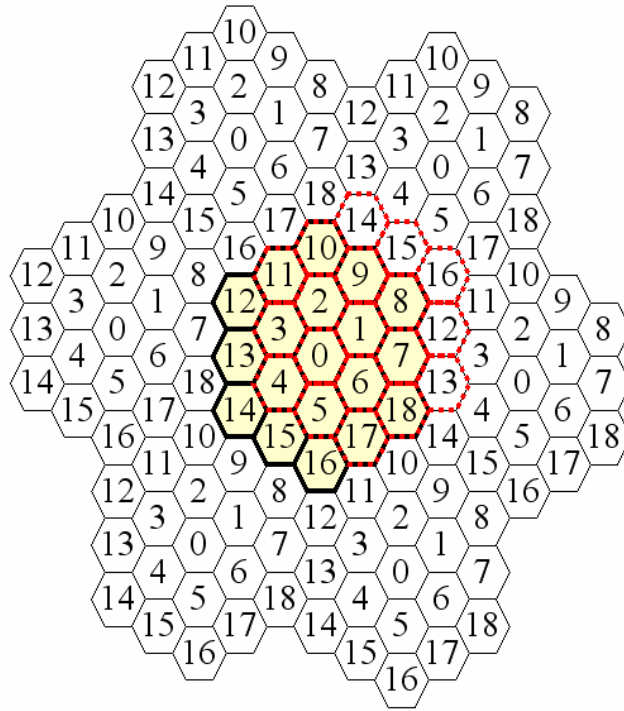

Figure 4-1 Base Station Wrap Around Deployment
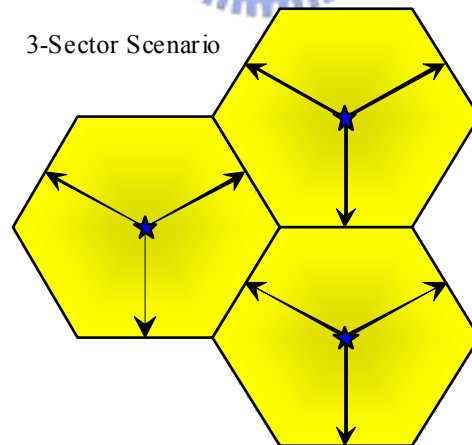

Figure 4-2 3 sectors for each base station

4.1.2 Link budget

The link budget settings follow the 802.16e requirements from an operator's perspective. Table 4-1 shows the 802.16e reference scenario that is used in this

simulation. The outdoor vehicular model is used to make the transmitting power and antenna parameters such as 46dBm for BS Tx power, 27dBm for SS Tx power, 17dBi for BS antenna gain, 3dBi for SS antenna gain and 30m for BS antenna height. The BS backoff that is used to avoid the RF circuit working in the non-linear region due to the peak to average power ratio (PARR) of OFDM system is 5dB. The common usage value of thermal noise density is -173.93 dB/Hz. The receiver noise figure of MSs is 9dB.

Table 4-1 Link budget

Scenario Parameter	Indoor	Outdoor to indoor	Outdoor vehicular
BS Tx power	27 dBm (0.5 W)	36 dBm (4 W)	46 dBm (40 W)
MS Tx power	17 dBm	17 dBm	27 dBm
BS ant gain	6 dBi	17 dBi	17 dBi
MS ant gain	0 dBi	0 dBi	3 dBi
BS ant height		15 m	30 m

In the real wireless channel model, the transmitted signal suffers the fading effect that causes the significant distortion to the signal quality. The fading can be classified into three parts : pathloss, shadow fading, and fast fading (multipath and Doppler effect). Pathloss and shadow fading are the large scale fading, and the fast fading is considered as the small scale fading. Only the pathloss and shadow fading are considered in this simulation. The pathloss model is correlated with the distance between the transmitter and the receiver. The longer distance between the transmitter and the receiver is, the more attenuation of the transmitted signal strength will be. In Winner D5.4 document [21], several pathloss models of LOS and NLOS are provided as Table 4-2. The cell radius of BS is 1km and the non-line of sight (NLOS) is considered, so the C2 scenario is used in this simulation.

Table 4-2 Pathloss model scenario

Scenario		Path-loss [dB]	Shadow fading standard dev.	Applicability range
A1	LOS	$18.7 \log_{10}(d[\text{m}])+46.8$	$\sigma = 3.1$ dB	$3\text{m} < d < 100\text{m}$
A1	NLOS	$PL(d) = 36.8 \log_{10}(d[\text{m}])+38.8$	$\sigma = 3.5$ dB	$3\text{m} < d < 100\text{m}$
B1	LOS	$22.7 \log_{10}(d[\text{m}])+41.0$	$\sigma = 2.3$ dB	$10\text{m} < d < 650\text{m}$
B1	NLOS	$0.096 \, d_1[\text{m}]+65+$ $(2.8-0.024 \, d_1[\text{m}]) \log_{10}(d_2[\text{m}])$	$\sigma = 3.1$ dB	$10\text{m} < d_1 < 550\text{m}$ $w/2 < d_2 < 450\text{m}$
C2	NLOS	$35.0 \log_{10}(d[\text{m}])+31.5$	$\sigma = 8$ dB	$50\text{m} < d < 5\text{km}$
D1	LOS	$PL(d) = 21.5 \log_{10}(d[\text{m}])+44.6$ $= 40.0 \log_{10}(d/d_{BP})+44.6+$ $21.5 \log_{10}(d_{BP})$	$\sigma = 3.5$ dB $\sigma = 6.0$ dB	$30\text{m} < d < d_{BP}$ $d_{BP} < d < 10\text{km}$
D1	NLOS	$PL(d) = 25.1 \log_{10}(d[\text{m}])+55.8$	$\sigma = 8.0$ dB	$30\text{m} < d < 10\text{km}$

The shadow fading model is to simulate the noise interference caused by the buildings, shelters and mountains on the transmission path. According to the discussion of [17,22], the correlation model for shadow fading is introduced here. The formula of the correlation is shown as following.

$$\rho(\Delta x) = e^{-\frac{|\Delta x|}{d_{cor}} \ln 2}$$

In this formula, ρ is the auto-correlation constant between two simulation sample points, and Δx which presents the distance between the two sample points is a function of sampling times, sampling duration, and user speed. The d_{cor} is the de-correlation distance. The value of the suburban macro, urban macro, and urban microenvironments are 200m, 50m, and 5m, respectively. The value of 5m is used in this simulation.

Figure 4-3 shows the diagram to calculate the signal-to-interference and noise ratio (SINR) in this simulation. The simulation parameters are based on the link budge, pathloss model and shadow fading model.
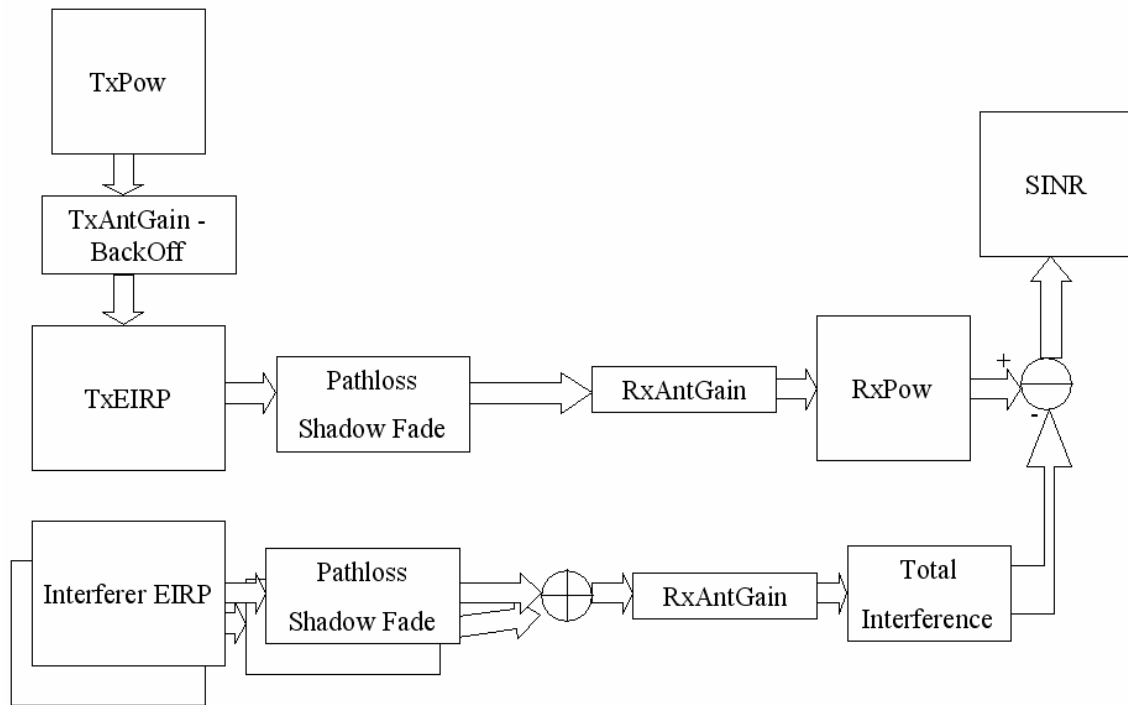

Figure 4-3 Diagram of SINR computation

4.1.3 Relay station deployment

In this simulation, the scenario of three relay stations for each base station is introduced. Figure 4-4 is the example of two-hop connection in the MR system.
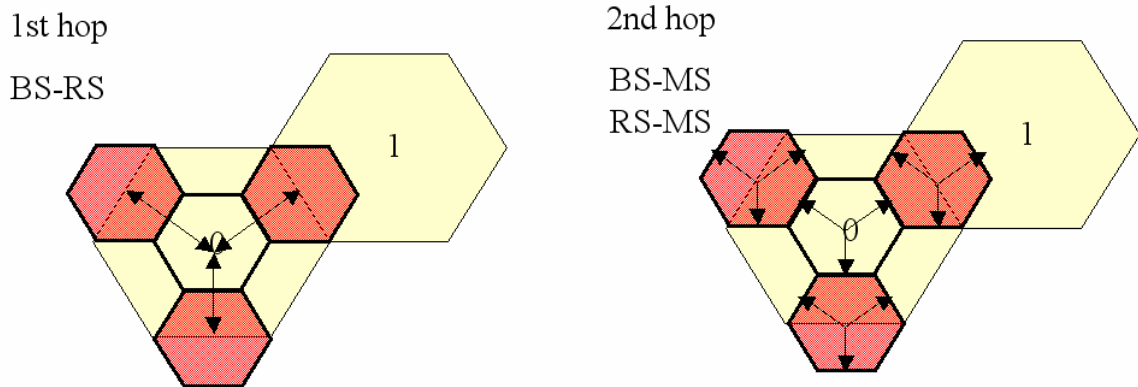
Figure 4-4 Example of RS deployment

4.2 Path reselection model setup

Two constraints are introduced into this proposed path reselection mechanism.

4.2.1 SINR

In this section, the multi hop situation is not considered. To calculate and deliberate on the link quality of single path between MS and current station and target station is the first consideration. Two factors need to be discussed in this criterion.

1.   SINR Strength :

$$\mathbf{SINR_{Target} > SINR_{Current}}$$

This is the first and most important factor that needs to be taken by MR-BS to decide whether to trigger the handover or not.

2.   SINR Stability :

For this constraint, two conditions are needed to be defined clearly.

A.   Min. $\text{SINR}_{\text{Target}}$ > Max. $\text{SINR}_{\text{Current}}$

For this case, skip the SINR standard deviation calculation and make this constraint true. Figure 4-5 shows this situation.

B.   Min. $\text{SINR}_{\text{Target}}$ < Max. $\text{SINR}_{\text{Current}}$

Calculate the SINR standard deviation of each possible path and find out the most stable path for MS handover. The SINR standard deviation comparison is as below formula. Figure 4-6 and 4-7 illustrates this case and HO symbol indicates when will MR-BS make the handover decision.

$$\mathbf{StdDev\ SINR_{Target} < StdDev\ SINR_{Current}}$$

If both of the above constrains are true, the MR-BS will consider making the

handover decision. Figure 4-8 shows the appropriate path reselection based on the strength and stability of link quality in a MR network.
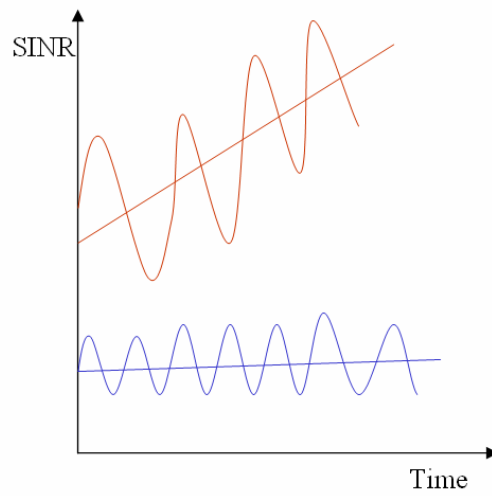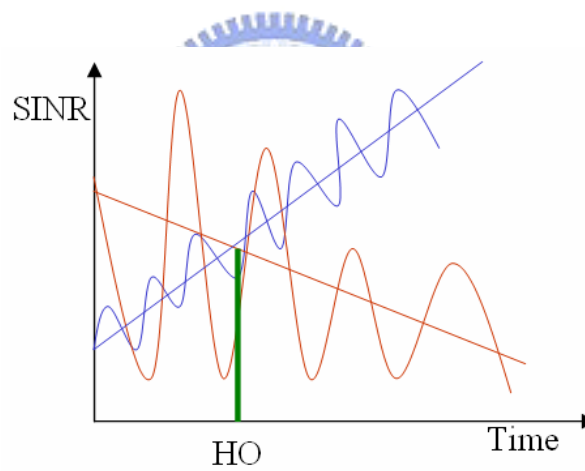

Figure 4-5 Example of SINR strength constraint

Figure 4-6 Example of SINR standard deviation constraint
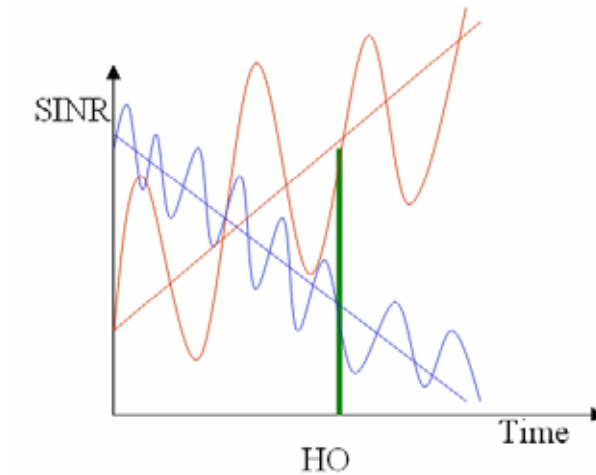
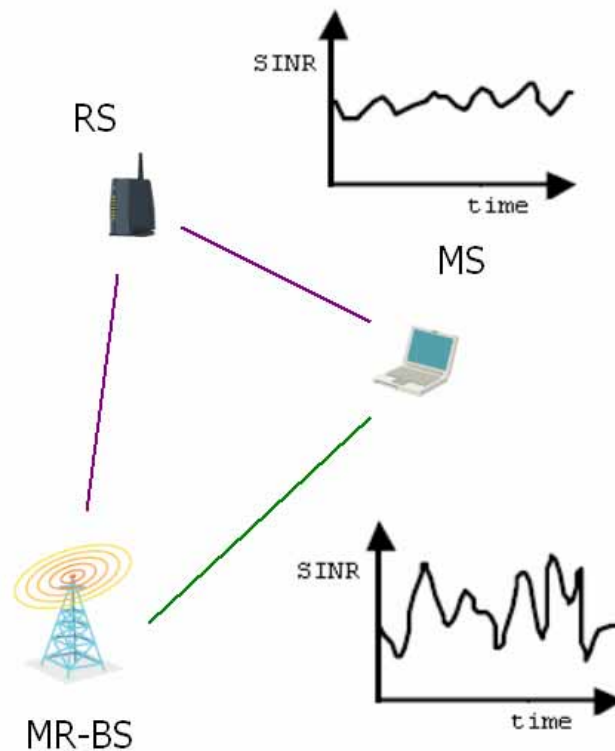**Figure 4-7 Example of SINR standard deviation constraint**

Figure 4-8 An appropriate path reselection based on the strength and stability of link quality in a MR network

4.2.2 Hop counts :

In this section, the multi hop situation is considered. Calculate and take care of the link quality of multi path. AMC comparison that is an important factor is introduced into this path reselection mechanism. The meaning of AMC comparison is to make sure that the throughput can be enhanced after handover with path reselection.

1. SINR Strength with marginal addition :

$$SINR_{RS\text{-}MS} > SINR_{MRBS\text{-}MS} + SINR_{margin}$$

If the target access station is a RS, a SINR margin must be considered as an additional factor to let MS to stay in the MR-BS's connection as far as possible.

2. AMC :

$$1/AMC_{MRBS\text{-}RS} + 1/AMC_{RS\text{-}MS} < 1/AMC_{MRBS\text{-}MS}$$

The effective throughput is a path reselection concern in this simulation. If the effective throughput of the multi-hop link is not as good as that of the single-hop link, the MR-BS may not consider triggering the MS handover. This constraint is to make sure that the throughput can be enhanced after handover with path reselection. The parameter is referenced to the data payload of P802.16 Rev2/D2. For example, the data payload of QPSK1/2 is 6 bytes, 16QAM1/2 is 12 bytes, and 64QAM1/2 is 18 bytes.

SINR strength comparison is an important factor while MS or BS makes the decision to trigger the handover procedure in 802.16e. In MR system, another key factor that is AMC (Adaptive Modulation and Coding) is introduced into this proposed path reselection mechanism. In the next chapter, the performance impact of each factor introduced into this proposed path reselection will be discussed.

Chapter 5
Simulation Result

In this chapter, the discussion of some parameters that impact the Ping-Pong effect is presented. The simulation result is divided into two sections. The first section introduces what parameters and how to affect the Ping-Pong handover and non Ping-Pong handover. The second section discusses the key factor in the proposed path reselection mechanism of this simulation.

5.1 Analysis of MS handover without path reselection mechanism

In this section, the factors that impact the Ping-Pong effect are discussed first. There are three factors analyzed here, number of relay stations, MS mobility, and number of users.

5.1.1 Ping-Pong effect versus number of relay stations

As the number of relay stations increases, the possibility and frequency of MS handover will increase. For this analysis, three different kind of number of relay stations are discussed, zero RS, three RSs and six RSs. As showed in Figure 5-1, it is obvious that the Ping-Pong effect increases as the numbers of relay stations increases. The main peak of Ping-Pong handover counts happen in 1000mS (1S). MS handovers to target access station that was the previous access station in 1S, and this case is a serious Ping-Pong effect. Although in the non-RS system, there is a certain number of Ping-Pong handovers that may be the unnecessary handover and the Ping-Pong handovers ratio is 36%. Figure 5-2 shows that the Ping-Pong handovers ratio over the total handover counts. As the numbers of relay stations increases, the frequency of MS handovers increases and the ratio of Ping-Pong handovers decrease. Because of the increasing access station, the MS has higher frequency to handover to another access station that is not the previous access station.
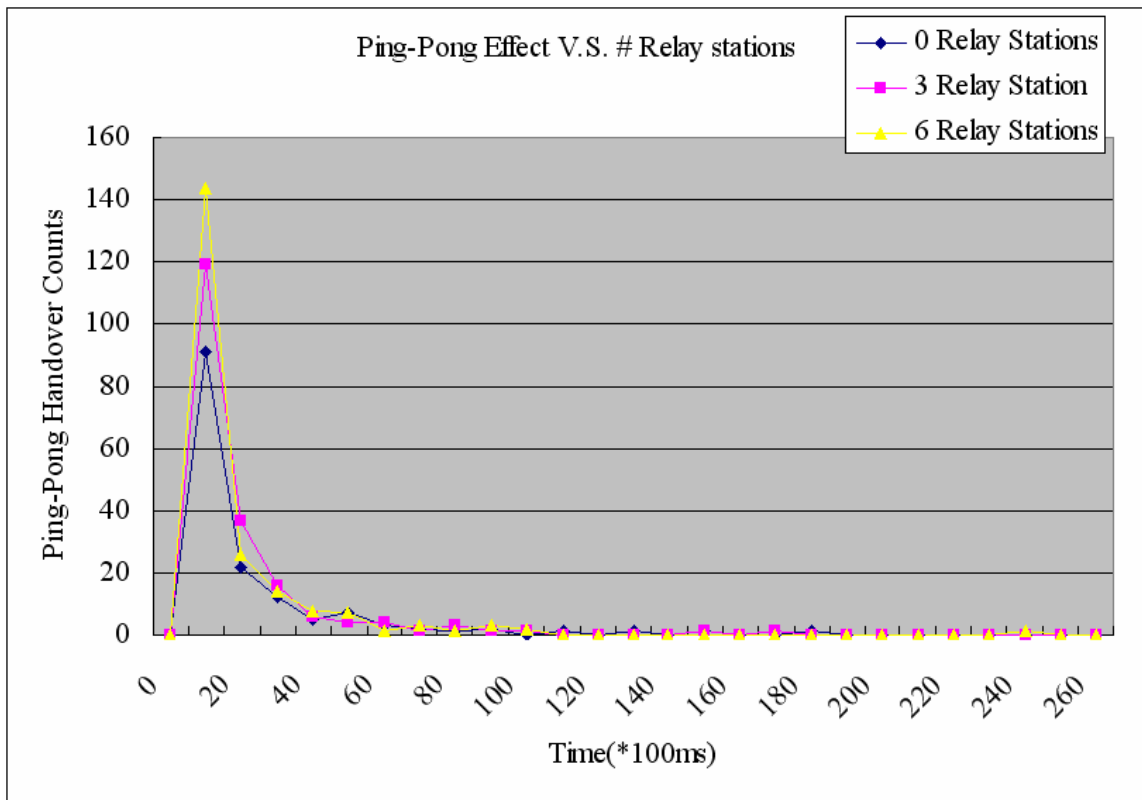
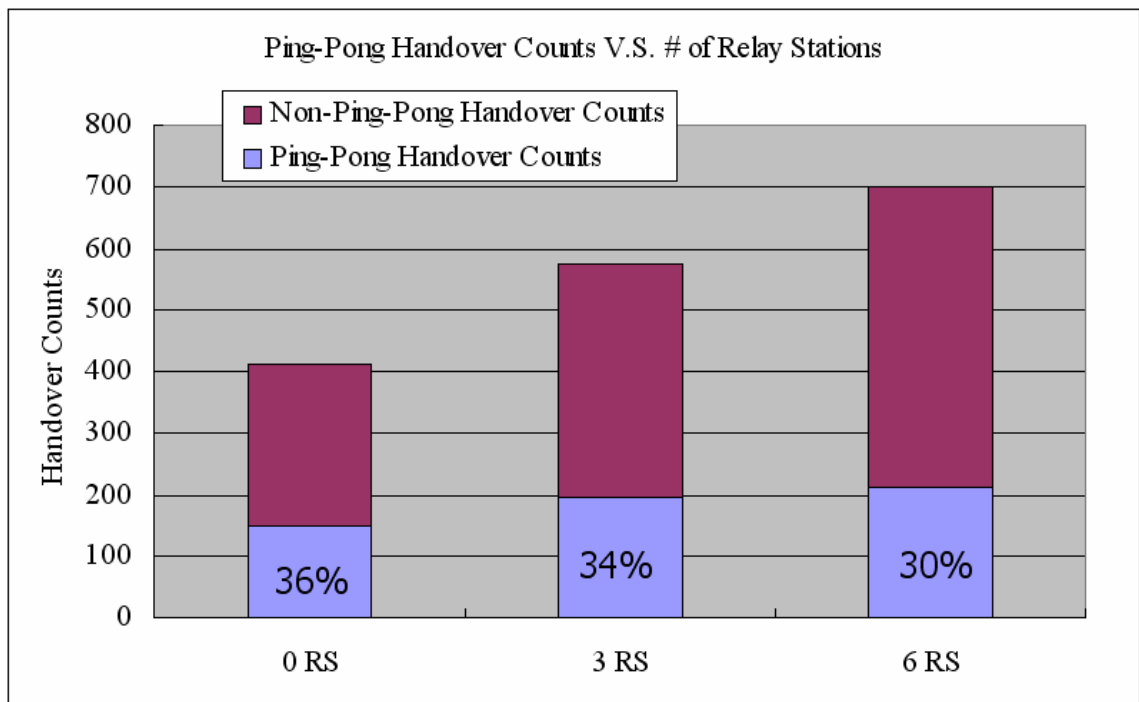**Figure 5-1 Ping-Pong Effect V.S. numbers of relay stations**

Figure 5-2 Ping-Pong Handover Counts V.S. numbers of relay stations

5.1.2 Ping-Pong effect versus MS mobility

As the MS mobility decreases, the possibility and frequency of MS handover will decrease. For this analysis, three different kind of Ms mobility are discussed, 50km/h, 25km/h and 10km/h. As showed in Figure 5-3, it is observed that the Ping-Pong effect decreases as the MS mobility decreases and the duration of Ping-Pong handover increases from 1S to 2S. Figure 5-3 and 5-4 show that as the MS mobility decreases, the total handovers and the ratio of Ping-Pong handovers decrease rapidly. When Ms moves slower, it will stay in a more stable environment and have less opportunity to handover to another access station and the duration of handover will also extend.
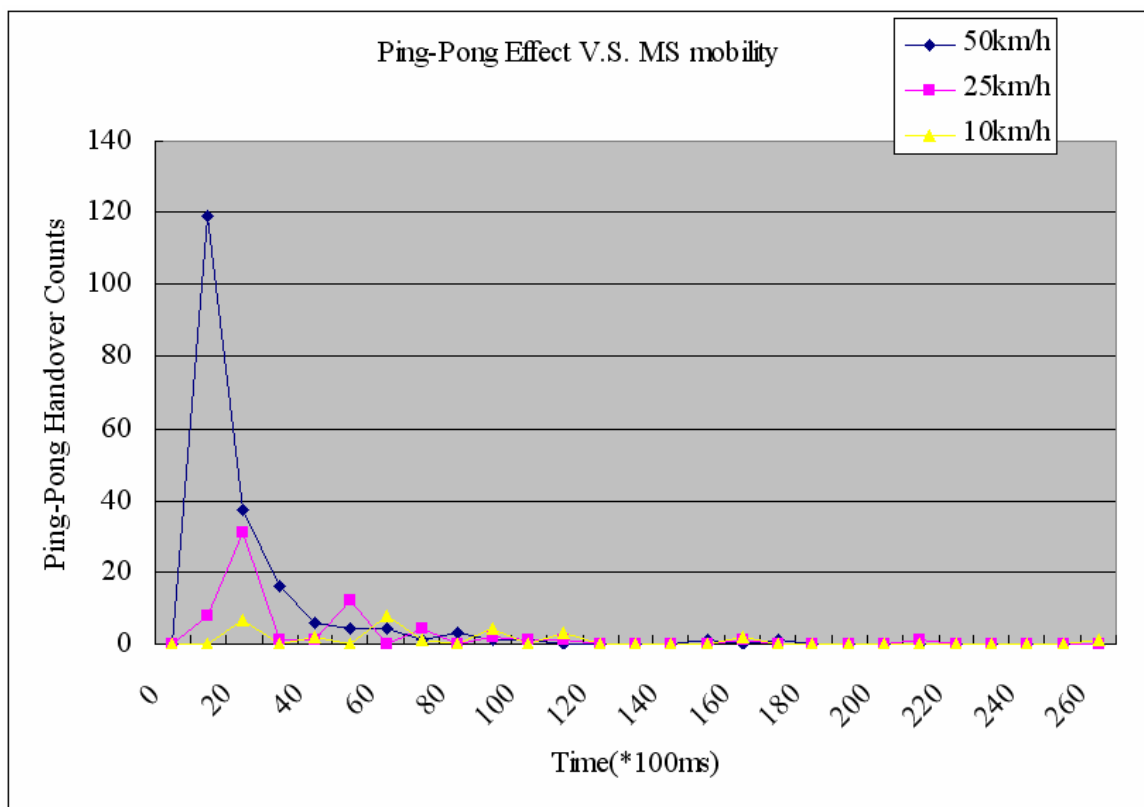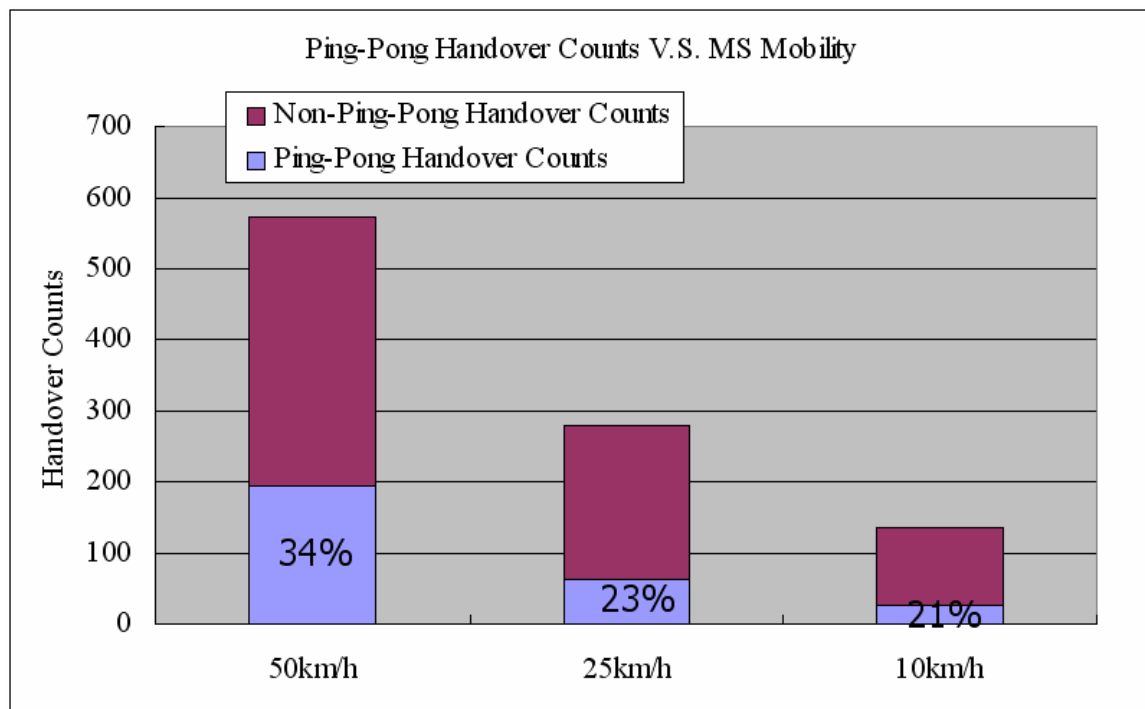

Figure 5-3 Ping-Pong Effect V.S. MS mobility

Figure 5-4 Ping-Pong Handover Counts V.S. MS mobility

5.1.3 Ping-Pong effect versus number of users

As the users increases, the possibility and frequency of MS handover will increase. For this analysis, three different kind of number of users are discussed, 60 users, 120 users and 180 users. As showed in Figure 5-5, it tells that the Ping-Pong effect increases, as the number of users increases and the main peak of Ping-Pong handover remains 1S. Due to the increasing number of users, the Ping-Pong handover counts increase proportionally. Figure 5-6 also shows that total handover counts and Ping-Pong handover counts increase as number of users increases. Although the Ping-Pong and total handovers increase, the ratio of the Pin-Pong handovers remains the same.
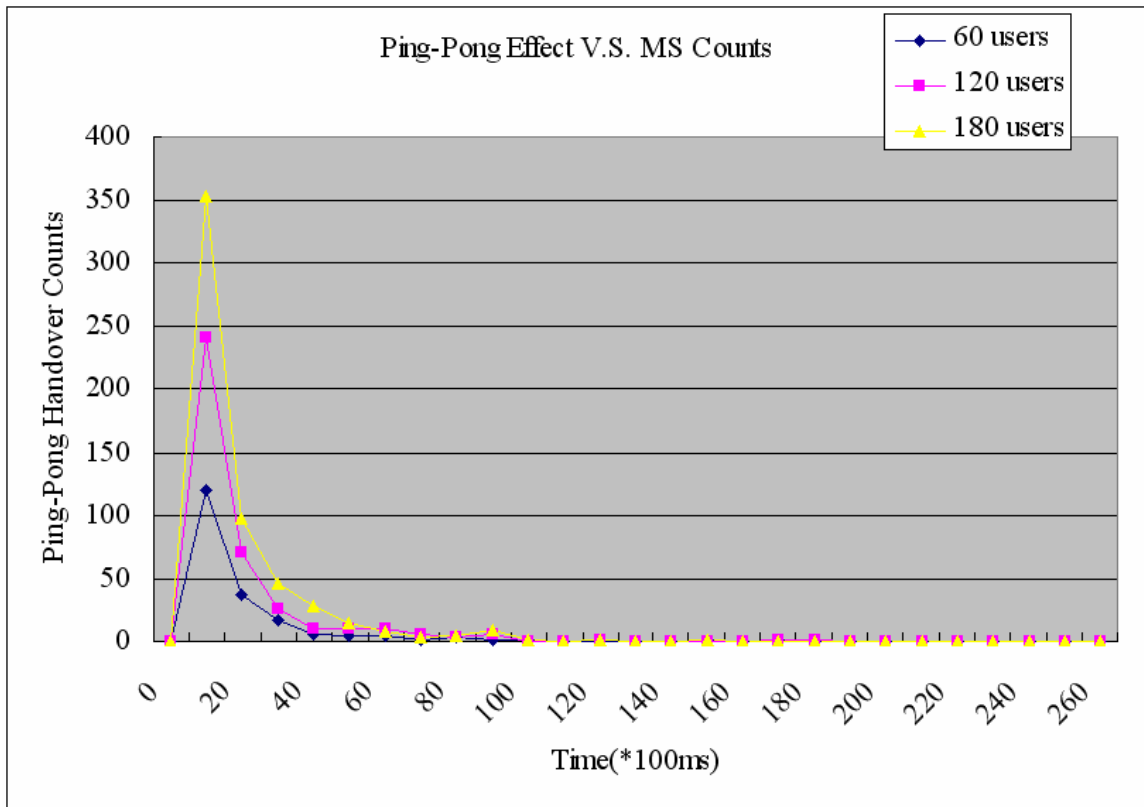
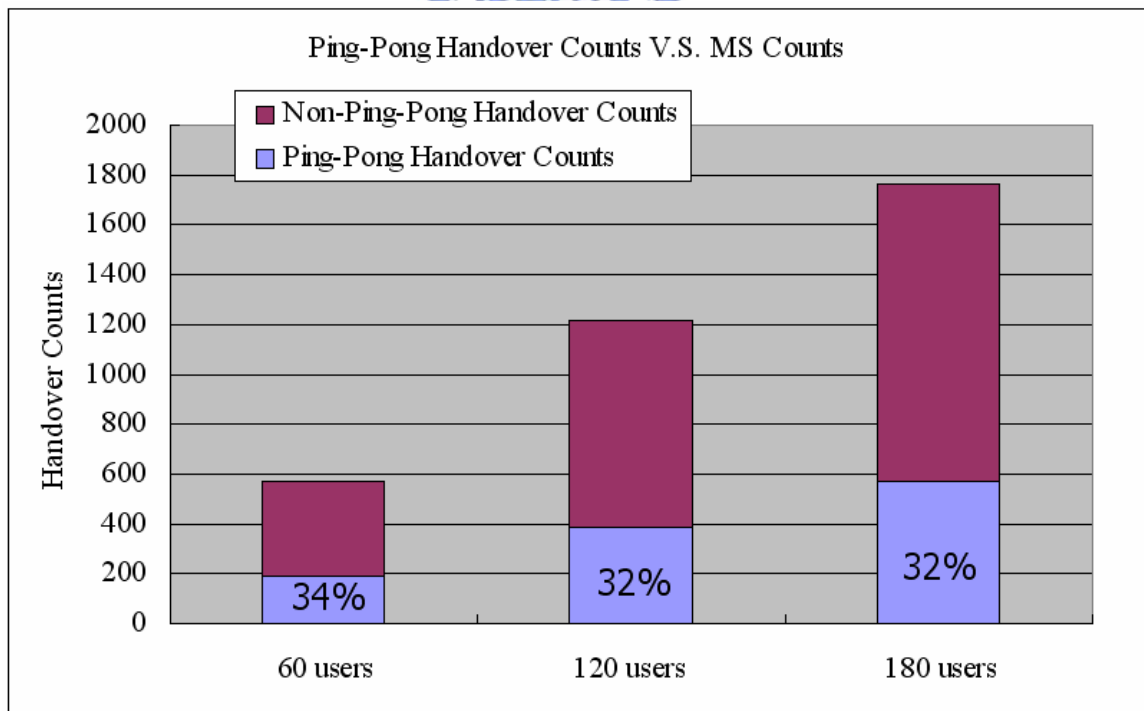**Figure 5-5 Ping-Pong Effect V.S. MS Counts**

Figure 5-6 Ping-Pong Handover Counts V.S. MS Counts

5.2 Analysis of MS handover with path reselection mechanism

In this section, all the constraints introduced into the proposed path reselection mechanism are separated to analyze the individual impact on the Ping-Pong Effect reduction. As described in the Chapter 4, two main factors are induced into this path reselection mechanism, SINR and Hop Counts. The detail constraints of these two factors are listed as below.

1. SINR :
   - SINR Strength :

     $$\mathbf{SINR_{Target} > SINR_{Current}}$$

   - SINR Stability :

     $$\mathbf{Min.\ SINR_{Target} > Max.\ SINR_{Current}\ OR}$$
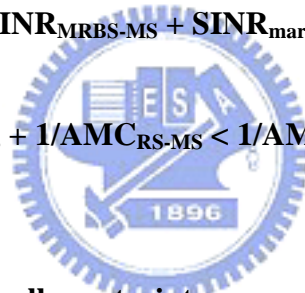
     $$\mathbf{StdDev\ SINR_{Target} < StdDev\ SINR_{Current}}$$

2. Hop Counts :
   - SINR Strength with marginal addition :

     $$\mathbf{SINR_{RS\text{-}MS} > SINR_{MRBS\text{-}MS} + SINR_{margin}}$$

   - AMC :

     $$\mathbf{1/AMC_{MRBS\text{-}RS} + 1/AMC_{RS\text{-}MS} < 1/AMC_{MRBS\text{-}MS}}$$

5.2.1 Ping-Pong effect versus all constraints

First, all constraints of path reselection are introduced into the simulation to observe the Ping-Pong handovers reduction. The $SINR_{margin}$ parameter is adjusted to see how this parameter can affect the Ping-Pong Effect. Figure 5-7 and Figure 5-8 show that the Ping-Pong effect is reduced almost 66% at the main peak and 50% of total Ping-Pong handovers. The Ping-Pong handover ratio and total handover counts are almost the same with different $SINR_{margin}$ so the $SINR_{margin}$ parameter is not a key factor after this path reselection mechanism uses all constraints to reduce the Ping-Pong Effect.

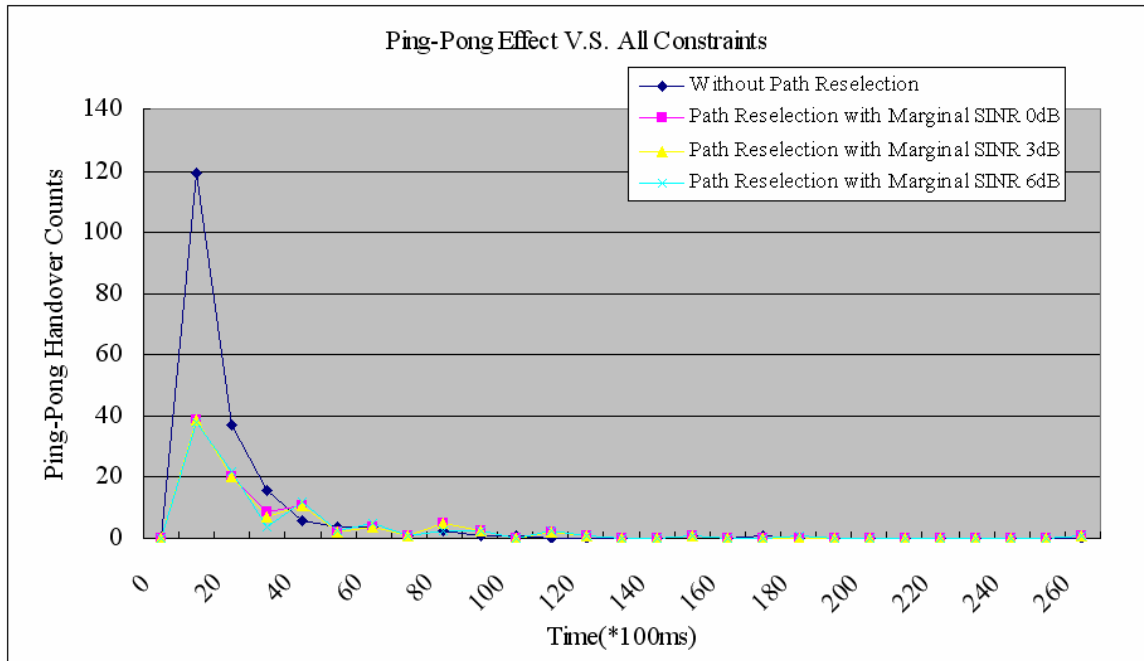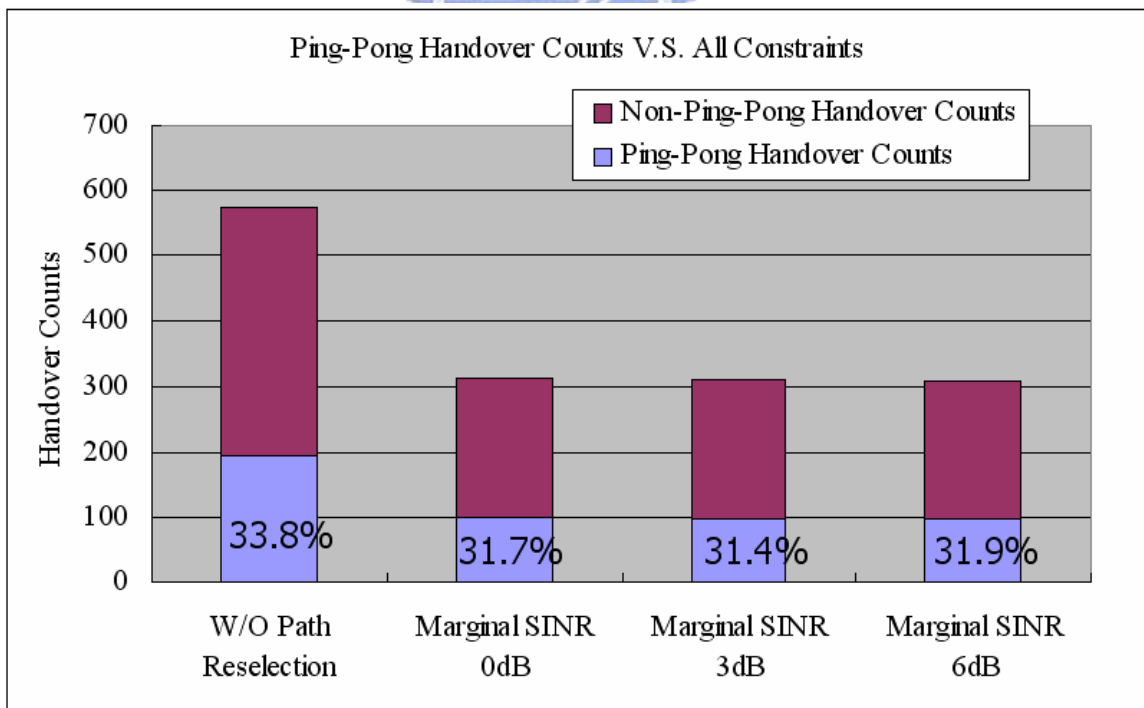**Figure 5-7 Ping-Pong Effect V.S. All Constraints**

Figure 5-8 Ping-Pong Handover Counts V.S. All Constraints

5.2.2 Ping-Pong effect versus only SINR strength marginal addition

Although the result of 5.2.1 shows that the $SINR_{margin}$ parameter is not a key factor while all constraints are used, it is interesting to analyze the Ping-Pong reduction by using this parameter. Only the constraint, $SINR_{RS-MS} > SINR_{MRBS-MS} + SINR_{margin}$, is to reduce the Ping-Pong handover. Figure 5-9 shows that as the $SINR_{margin}$ parameter increases, the Ping-Pong handover counts decreases. This parameter may not be the most important factor but it really reduces the Ping-Pong effect. If the $SINR_{margin}$ parameter is large enough, it may be the key factor of this path reselection mechanism. Figure 5-10 shows that if the $SINR_{margin}$ parameter is not zero, the Ping-Pong handovers and total handover counts can be reduced proportionally as $SINR_{margin}$ increases.
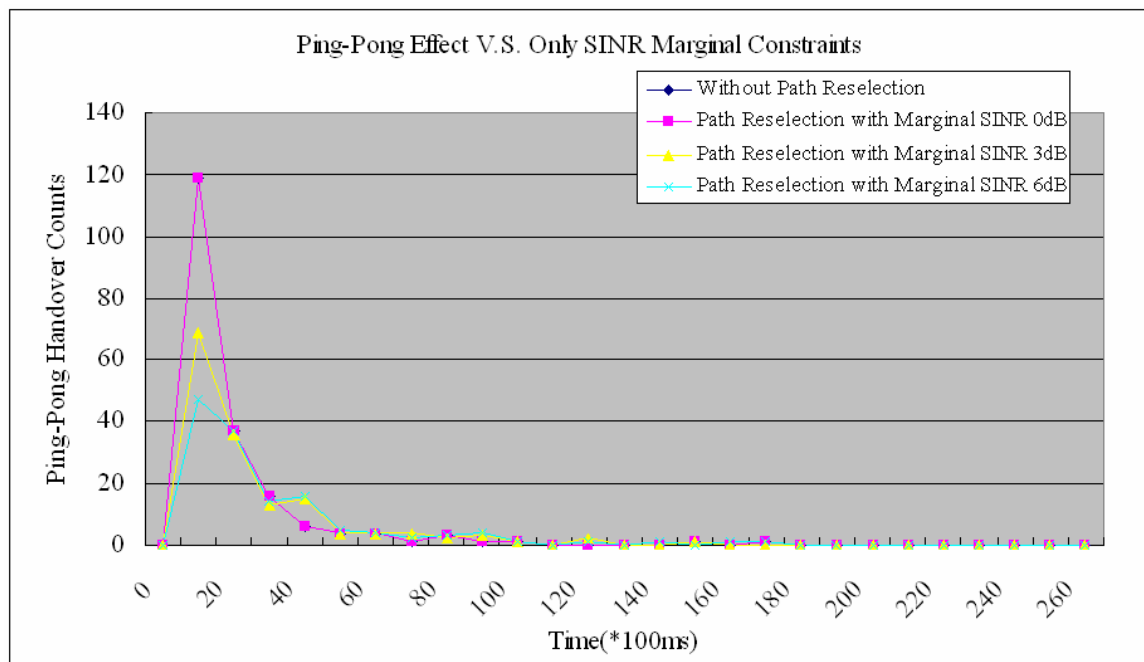

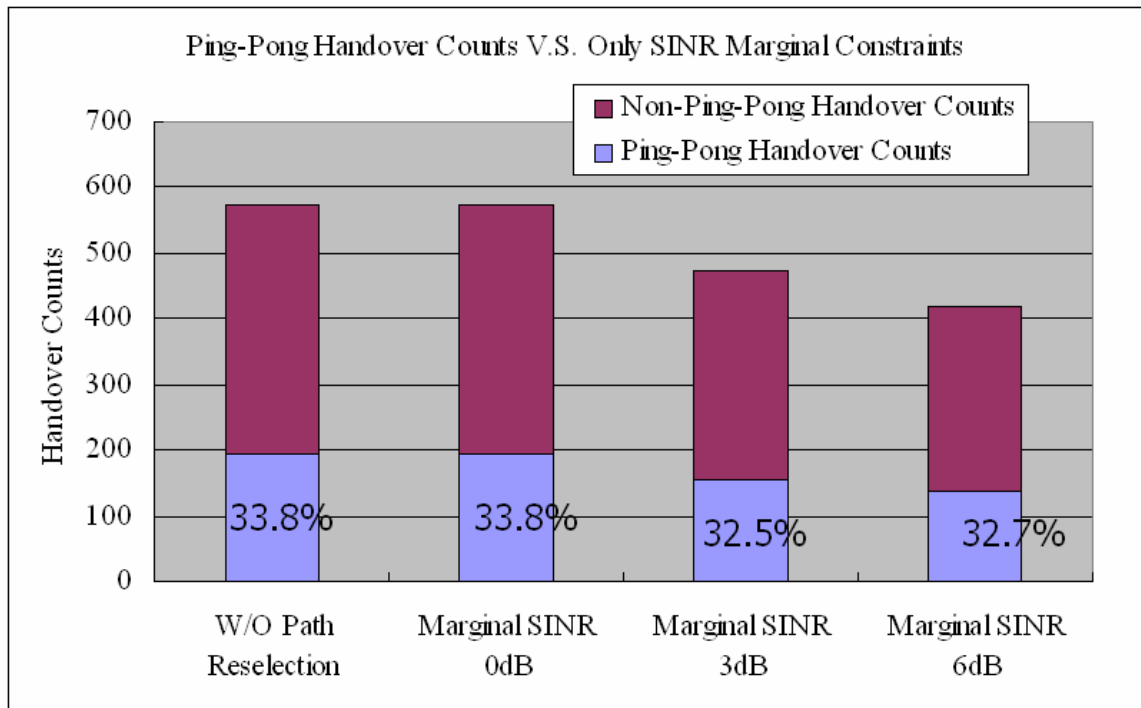**Figure 5-9 Ping-Pong Effect V.S. Only SINR Marginal Constraints**

Figure 5-10 Ping-Pong Handover Counts V.S. Only SINR Marginal Constraints

5.2.3 Ping-Pong effect versus different constraint

In this sector, all constraints are separated to analyze the impact on Ping-Pong effect to find out the most important factor. Four conditions are discussed according to Figure 5-11 and Figure 5-12.

1. Path reselection with only AMC:

$1/AMC_{MRBS-RS} + 1/AMC_{RS-MS} < 1/AMC_{MRBS-MS}$

The simulation result shows that the AMC constraint is the most important factor for this proposed path reselection mechanism. By this AMC constraint, the main peak of Ping-Pong handovers reduction is 66%, the total Ping-Pong handovers reduction is 51% and the total handovers reduction is 46%. This constraint also decreases the Ping-Pong handover ratio from 33.8% to 30.5%.

2. Path reselection without AMC:

Without AMC constraint, the path reselection mechanism can decrease the Ping-Pong handovers and total handovers because of the other constraints. Other constraints without AMC can also reduce 50% of

Ping-Pong handovers.

3. Path reselection with SINR MinMax Comparison:

Min. $SINR_{Target}$ > Max. $SINR_{Current}$

This constraint can reduce the main peak of the Ping-Pong handovers but increase a little bit of the total Ping-Pong handovers. It may not be the right individual constraint of path reselection. This constraint should be combined with other constraints.

4. Path reselection with SINR StdDev Comparison:

StdDev $SINR_{Target}$ < StdDev $SINR_{Current}$

Although this constraint can reduce the Ping-Pong handovers and the total handovers, the impact of reducing the Ping-Pong effect is not so obvious. This constraint is not the key factor as the AMC constraint.

The AMC constraint is the most key factor of all constraint of this proposed path reselection mechanism.
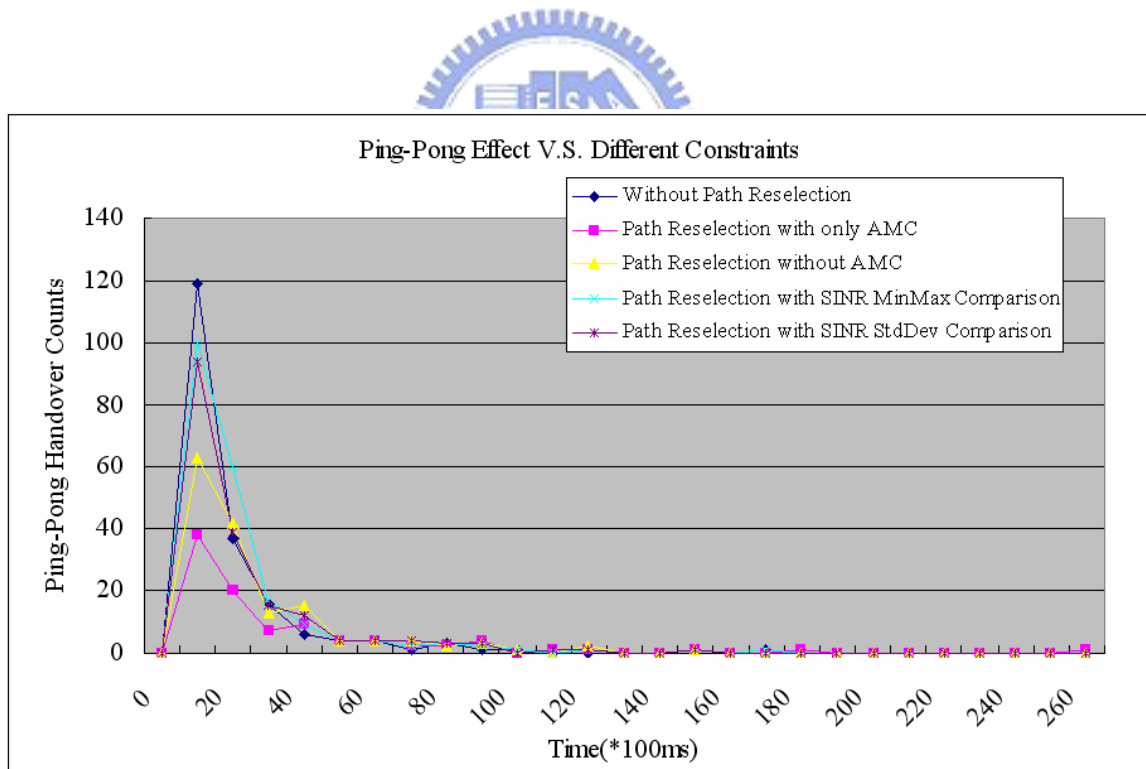

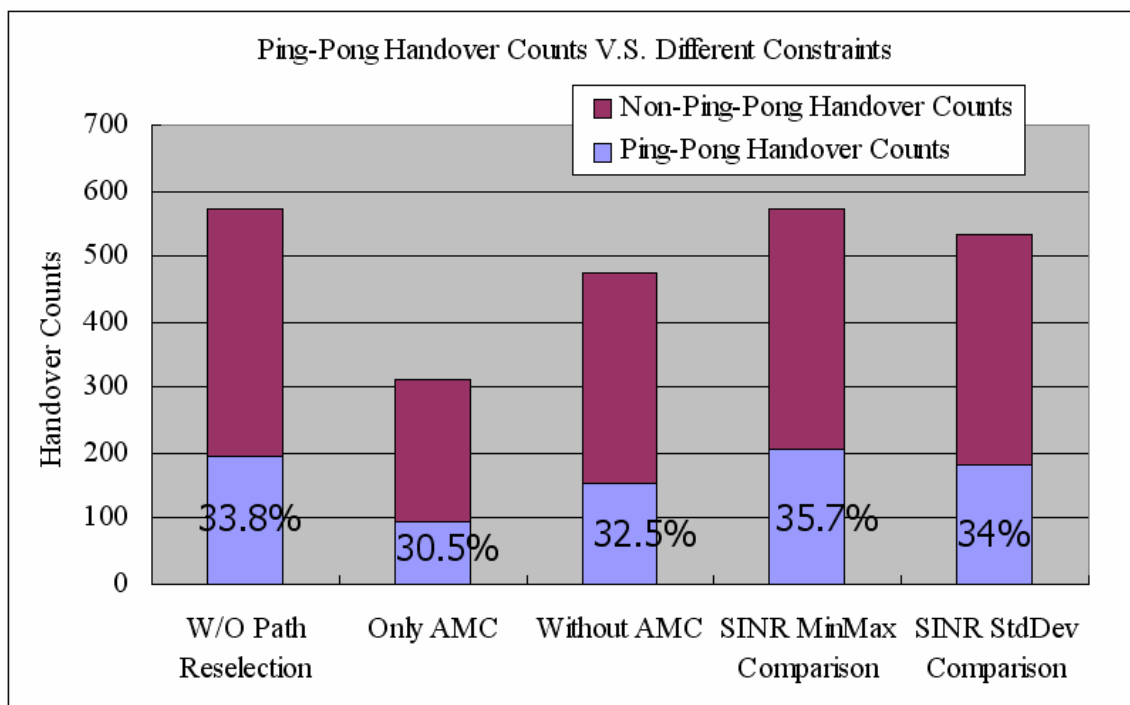**Figure 5-11 Ping-Pong Effect V.S. Different Constraints**

Figure 5-12 Ping-Pong Handover Counts V.S. Different Constraints

5.2.4 SINR comparison

In this section, the SINR before handover and SINR improvement after handover are discussed. This discussion is to realize whether the path reselection mechanism can select the right MS to handover or not. Figure 5-13 shows that the path reselection with the AMC constraint and all constraints can select the MS with low enough SINR to start the handover procedure. After Ms handovers to a new access station, MS can gain about 10dB SINR improvement. It is the same as the result by using the path reselection with all constraints. For the handover procedure without this proposed path reselection mechanism, the SINR of MS before handover is higher than other condition. It also gains the lowest SINR improvement of MS after MS finishes the handover procedure. This result indicates that the handover without this path reselection mechanism may select the MS that may not really need to handover to another access station.
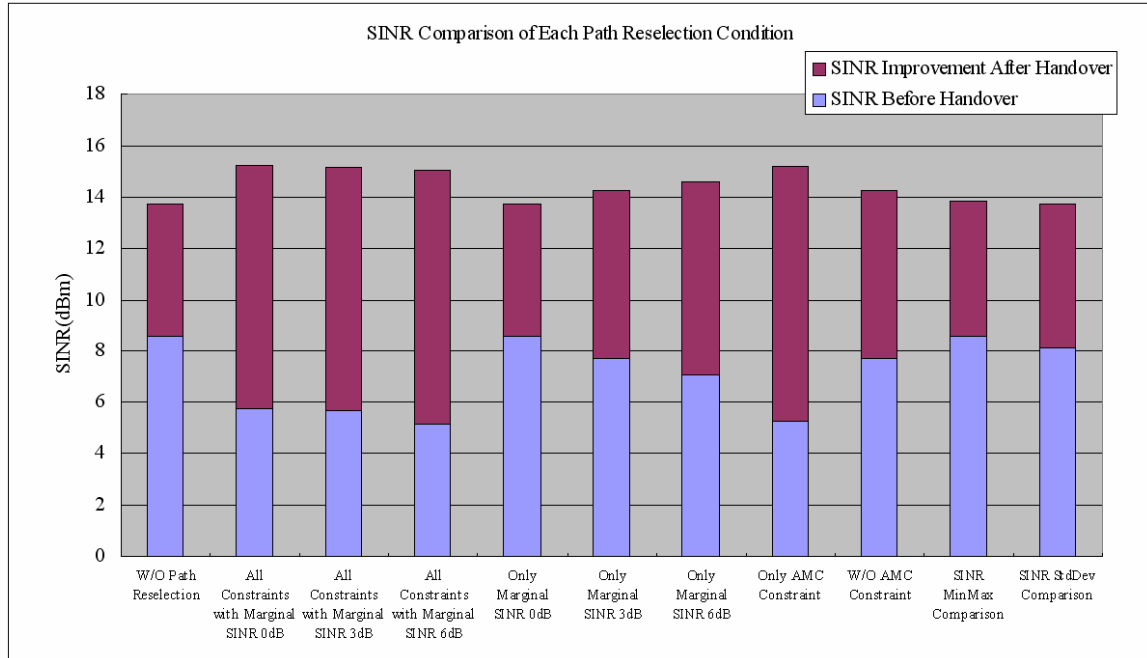
Figure 5-13 SINR Comparison of Each Path Reselection Condition

Chapter 6

Conclusion and future work

After the relay station is introduced into the 802.16e system, some issues may happen or enhance. Ping-Pong effect is one of these issues that may cause the ineffective resource usage or increasing system loading. Although one of the purposes of relay station deployment is throughput enhancement, the wrong handover decision may not enhance the throughput. This proposed path reselection can help MR-BS to select the correct MS and make the right handover decision.

The Ping-Pong effect is affected by some factors. In this simulation, three factors, number of relay stations, MS mobility, and number of users, are discussed. The Ping-Pong handovers increase due to the increment of the number of relay stations, MS mobility and number of users. The ratio of the Ping-Pong handovers presents the different result. As the number of relay stations increases, MS has more opportunity to handover to another access station that is not the previous access station. This situation may cause the decrement of the Ping-Pong handovers ratio. If the MS is on a higher speed, it may handover very often due to the unstable environment and this will increase the Ping-Pong handover ratio. For the number of users, the ratio of Ping-Pong handovers remains the same although the total handovers increases as the number of users increases.

There are four factors introduced into the proposed path reselection: SINR strength, SINR stability, SINR Strength with marginal addition, and AMC. According to the simulation result, this proposed path reselection mechanism can reduce almost 66% of the main peak and 50% of total Ping-Pong handovers. After analyzing the performance of each factor, the AMC factor is the most important one. AMC is considered as a throughput concern. This path reselection mechanism using AMC to make sure that the throughput can be enhanced after handover. Not only the link quality (SINR) but also the throughput enhancement are considered to make the handover decision by the MR-BS.

The SINR comparison is the index to analyze the performance of the path reselection mechanism. It is obvious that this proposed path reselection mechanism can choose the MS that really need to handover and also make the MS to handover to the right target access station. The SINR improvement of this mechanism is much higher than that of the handover without this mechanism.

For the next step, some futurer work may be continued. First, study the impact of MS handover using path reselection in non-transparent RS system. Next, find out the difference of system performance and handover procedure of fixed RS system and mobile RS system. Try to implement the path reselection mechanism into the mobile RS system. Finally, study the feasibility to implement this proposed path reselection mechanism into the real RS system.

Reference

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