

# 國立交通大學

電機學院微電子奈米科技產業研發碩士班

## 碩士論文

針對行動多躍中繼系統在行動 WiMAX 系統中之無線資源管理效能之研究

**Radio Resource Management for Mobile Multihop Relay(MMR) in Mobile**

**WiMAX System**



研究生：朱家弘

指導教授：黃經堯 博士

中華民國九十七年九月

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研究生：朱家弘

**Student : Jia-Hung Ju**

指導教授：黃經堯

**Advisor : Ching-Yao Huang**

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學生: 朱家弘

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## 摘 要

隨著使用者對於高速無線資料傳輸的需求增加，行動 WiMAX 系統不僅僅能滿足此需求，並且已經成為未來 3.5 代、第 4 代行動通訊系統的候選人之一。但是在多媒體應用的持續發展下，除了高傳輸速率、高頻寬的無線通訊服務已經是必需的條件，還必須考慮到整個基地台底下用戶的平均傳輸速率與整體服務區域的提升。因此行動多躍中繼系統 (MMR) 等提升服務品質的系統，勢必會成為下一代行動通訊開發的基本技術。基於此多躍中繼系統的規範 (IEEE802.16j) 即因醞而生。

在本論文中，將針對在有多躍中繼系統的支援的情況下，對於離基地台較遠或是傳輸通道情況較差的使用者，給予一定程度的中繼傳輸服務品質保證，進而增加系統使用者容量或涵蓋範圍。因此我們發展行動 WiMAX 模擬平台，建立了包含基礎無線資源管理以及可以支援多躍中繼系統運作的 MAC 層。在我們的模擬當中，我們同時也考慮了在即時與非即時混和式服務下的傳輸品質要求下，做出有效的通道選取。在滿足使用者傳輸品質要求的前提下，有效的分配無線傳輸資源。根據模擬數據的分析，我們可以得知，在有多躍中繼系統的支援下，能夠有效的提升在整體的使用者的平均傳輸速率並減少同頻干擾進而提升傳輸品質及系統的使用者容量。

# Radio Resource Management for Mobile Multihop Relay(MMR) in Mobile WiMAX System

Student: Jia-Hung Ju

Advisor: Ching-Yao Huang

Industrial Technology R & D Master Program of  
Electrical and Computer Engineering College  
National Chiao Tung University

## ABSTRACT

The mobile WiMAX which provide high speed transmission over large area has been adopted as one of the candidates of next generation communication system. But, with higher demand of multi-media application, not only high data rate and high bandwidth is necessary for wireless transmission, but also to consider whole cell average throughput, and coverage extension. Consequently, the Mobile Multihop Relay (MMR) system will be the solutions of future wireless system. Base on those idea the Mobile Multihop Relay (MMR) system were establish in IEEE 802.16j.

In this thesis, we apply Mobile Multihop Relay (MMR) system on mobile WiMAX to investigate the system level performance analysis when poor RF condition users are served with relay. Besides support poor users, we also consider the Quality of Service (QoS) requirements of mixed traffic services. As the result, we build a simulation platform for mobile WiMAX with basic Radio Resource Management (RRM) and Mobile Multihop Relay (MMR) enabled MAC layer. We adopt an effective path selection to consider simple scheduling algorithm for QoS guarantee and SINR enhancement for poor users. In the simulation result, the cell average capacity can be increase significantly because of the Mobile Multihop Relay (MMR) can help the partial poor RF user upgrade their AMC. With Mobile Multihop Relay (MMR) system, the SINR is enhanced so that the transmission quality is promoted and increase the system capacity.

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時光飛逝，轉眼間我的碩士生涯即將要結束了。在這一段驚濤駭浪的求學過程裡，體會到了修課上、研究上的痛苦。雖說鐵打的研究室，流水的學生，但是在我研究的過程中，隨時都有堅強的研究團隊來陪伴與伺候我，在此謝謝你們的 Fully Support。

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2008.09. 於 Wintech 交大 竹塹風城

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# CHAPTER 1

## INTRODUCTION

In wireless systems, the efforts have been made to increase the cell edge data rates to increase throughput. In different transmission environment, the Institute of Electrical and Electronic Engineers (IEEE) setup the relative standards which can be classified as WWAN (Wireless Wide Area Network use IEEE802.20), WMAN (Wireless Metropolitan Area Network use IEEE802.16), WLAN (Wireless Local Area Network use IEEE802.11), WPAN (Wireless Personal Area Network use IEEE802.15). The IEEE standard 802.16 which always represent as Worldwide Interoperability for Microwave Access (WiMAX) is one of wireless air interface technology in Wireless Metropolitan Access Network (WMAN). The first WiMAX standard IEEE802.16 was approved in 2001, the main function was working in 10~66GHz Line of Sight (LOS) wireless broadband service. To overcome the disadvantage of LOS usage only, the IEEE802.16a is completed address in 2~11GHZ with Non Line of Sight condition (NLOS) in 2003. The IEEE802.16-2004 standard [1] (IEEE802.16d) is the upgrades of the IEEE802.16a standard which was about the last version of fixed user location by radio link. The IEEE802.16e standard [2] was extended the IEEE802.16d which provides the support of mobile user in cellular deployments. In some case, when user is in the dead spot or in the service edge, the link quality was degrading quickly. The vendors need to consider the wire-line backhaul, and setup a new base station. But the complexity and the cost will be a big issue. In today's integrated circuit technology, the cost on one relay station (RS) compares with one base station is almost the 1/15. For this reason, on August 2007, IEEE802.16j TG has ended up finalizing IEEE802.16j Draft 1[3].

The performance analysis of relay placement in WiMAX has been investigated [4] [5]. The author was only focuses on one relay station (RS) simulation. In [6], the relay performance analysis is only focus on a new frame structure. In [7], the performance analysis was focus on the capacity reduction by increase of hop number in multi-hop relay system. In this thesis, we focus on IEEE802.16j mobile system level performances simulation. The performance analysis was adopted Mobile Multihop Relay (MMR) system technique, and use different parameter to evaluate the system performances. In the simulation, we employ Early Deadline First (EDF) [8] scheduling algorithms to analyze the system performance. Detail system level simulation will use mixed traffic [9] [10] (VoIP, HTTP, FTP) and single traffic to

simulate the throughput versus user quantity. Finally, we will try to find more efficient ways of utilizing radio resource.

The organization of this thesis is as follows. In Section II, we describe the Mobile Multihop Relay System (MMR), and brief introduction the PHY and MAC layer overview. In Section III, we present Simulation Setup. In Sections IV, Simulation result. Finally the conclusion and future works are provided in Sections V.



# CHAPTER 2

## INTRODUCTION OF MOBILE MULTIHOP RELAY SYSTEM (MMR)

In this chapter, first we will introduce the IEEE802.16 system, relay station system technology and benefit. Finally, we will brief overview the system architecture: Medium Address Control (MAC) & Physical Layer (PHY) of 802.16e & 802.16j.

### 2.1 IEEE802.16d/e/j System Introductions

IEEE802.16d standard consists of two kind of station: subscriber station (SS) and base station (BS). In IEEE802.16e architecture, the SS is replaced by mobile station (MS). In IEEE802.16j, they have another name user terminal (UT). The base station controls all the communicated resources in IEEE802.16d/e, but in IEEE802.16j the partial communicated resources was share with relay station (RS).

The communication paths between MS, RS and BS have two directions: downlink channel (from BS to MS/RS, RS to MS) and uplink channel (from MS to BS/RS, RS to BS). The access link is a radio link between an MR-BS and RS to an MS, or between an MR-BS and RS to a subordinate RS during network entry. The access link is either an uplink or downlink. The relay link is a radio link between an MR-BS and an RS or between a pair of RSs. This can be a relay uplink or downlink. Every MS and RS can deliver voice and data using common interface with different QoS requirement.

### 2.2 Relay System Technology and Benefits

The telecommunications company is very enthusiastic about the IEEE802.16 network, grow up fast in 2007. The IEEE802.16 system experienced a pang of finite bandwidth, shadow by building, that will cause the coverage holes and data flow non uniform. And if establishing a new residential area or business section, it will confront to build the infrastructural. In another situation, the user will fall victim to bad environment, like mountain, multi-storey building, and street corner. They will let the radio signal dramatically deteriorated.

We can clearly to find in Figure2-1[11], the base station contour line have many dead spot. In another situation, when user was in cell edge, it may need handoff (handover)

process like Figure 2-2. If the handoff process have abnormal or not perfect, the user might get the drop or error communication.

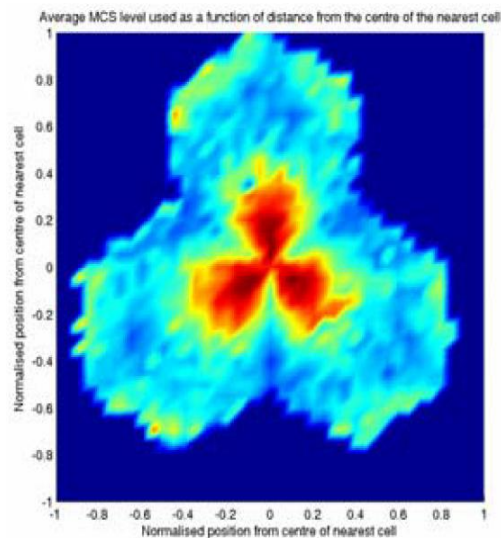


Figure 2-1 Base station contour line

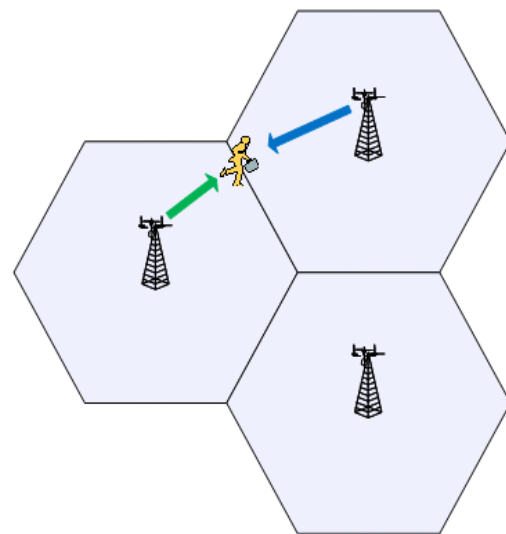


Figure 2-2 User in cell edge

In traditional, vender will consider three policies: 1. Increase the base station transmission power, 2. Establish more base station, 3. Repeater. But they were impracticable plan, because the first policy will contradict the telecommunications low [12], the second policy will increase the Operating expenditure (OPEX) like expensive redundant equipment, backup power equipment, backhaul maintain, the third policy will have an evil reaction that is amplify the total receive signal which about the effective and the noise. Hence, the relay station (RS) will be more attention.

### 2.2.1 The gains of Relay Stations

Then Mobile Multihop Relay (MMR) concept was publishing in 2005, the operator hopes that setup the Mobile Multihop Relay (MMR) spec and function can improve the 802.16 system performance. Hence, there are two benefits from relay station (RS) setup, one is throughput enhancement and another is coverage extension.

About the throughput enhancement, in the traditional IEEE802.16e the radio signal is approximate a “concentric circles”, near the base station will get better modulation and coding schemes (MCS), far side of the base station will get the poor. The sketch maps are as Figure 2-3. If we setup some relay station (RS) around the base station, the more relay stations (RS) will get better modulation and coding schemes (MCS). The diagram is Figure 2-4.

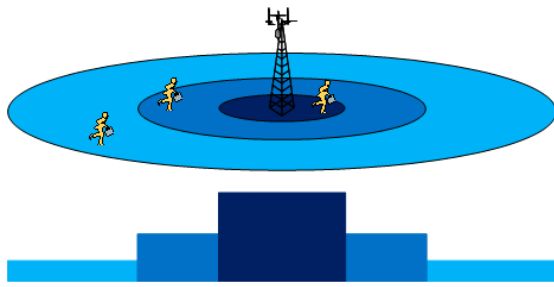


Figure 2-3 IEEE 802.16e

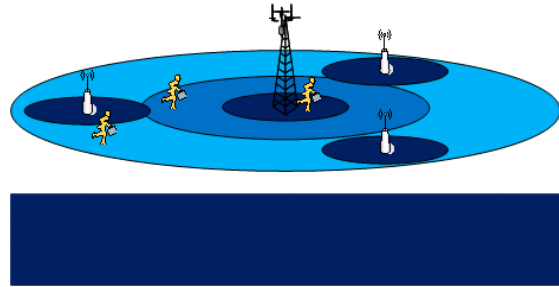


Figure 2-4 IEEE802.16j

About the coverage extension, if user is in the city outskirts like Figure 2-5, after consider the Operating expenditure (OPEX) unworthy to set a new base station, or in Manhattan-like environment, the radio signal will easy shadow by edifice, and the corner like the Figure 2-6. If set a relay station (RS) at the street corner or on the streetlamp, it might reduce the transmission power loss, and further it can realize the coverage extension.

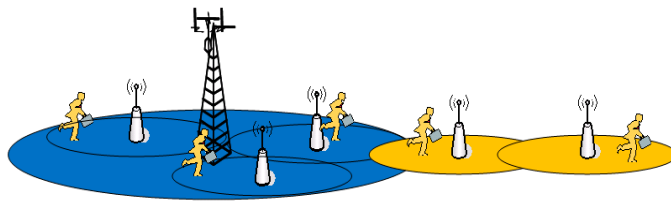


Figure 2-5 Coverage extension

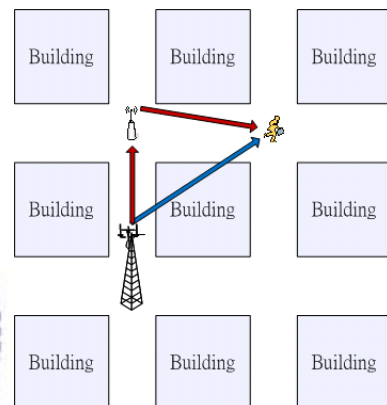


Figure 2-6 Coverage extension Manhattan-like

If the relay station (RS) quantity were increase, the system will become more complex. In system point of view, the total resource integrations need to be considered like frequency reuse [13],[14], Cooperative Relay[15],[16], and Relay station (RS) Grouping[17],[18], etc. The Cooperative Relay and Relay station (RS) Grouping diagram were show as Figure 2-7 and Figure 2-8.



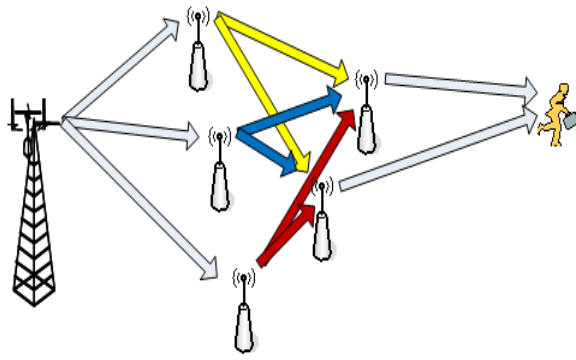


Figure 2-7 Cooperative Relay

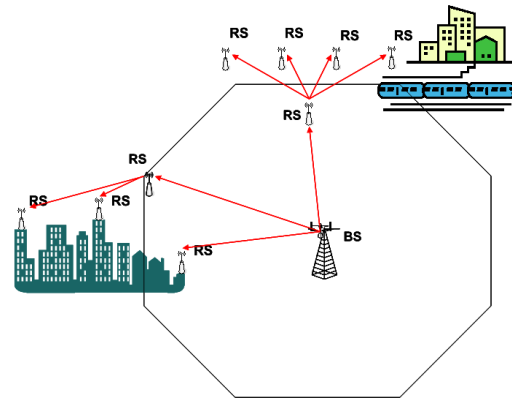


Figure 2-8 RS Grouping

## 2.2.2 Relay Stations Usage

To obtain best possible performance in the network, character of RSs and their placement must be carefully chosen. Hence, IEEE 802.16's Relay Task Group are defined four kinds of RS usage model to obtain the high system performance [19][20]: (1) Fixed infrastructure usage model (2) In-building coverage usage model (3) Temporary coverage usage model (4) Coverage on mobile vehicle usage model

### (1) Fixed infrastructure usage model

Fixed relay stations are utilized in this model that the owner is the infrastructure provider. The provider can be mounted on towers, poles, tops or sides of buildings, lamp posts, or in other locations. They can plan the locations of RS antennas to obtain LOS channels between the MMR-BS and RS, but this will not always be practical, so NLOS channel conditions on links between MMR-BS and RS can be expected.

### (2) In-building coverage usage model

In this model RSs are deployed to provide better coverage and higher throughput in a building, tunnel or underground such as on a subway platform. There can be a single RS or multiple RSs that services a small or big building, tunnel, underground location. The RS can be owned by the infrastructure provider or by the customer, and the function can be fixed or nomadic.

Between MMR-BS and RSs the channel conditions will usually be NLOS, but the RS might have one or more antennas mounted to the outside of the building to provide the access link between itself and the upstream RS or MMR-BS and one or more antennas mounted inside the building to provide coverage to downstream RSs and users.

### (3) Temporary coverage usage model

In this usage model the RS is deployed temporarily and nomadic to provide additional coverage or capacity in an area where the MMR-BS and fixed RS can not provide

sufficient coverage or capacity. In these situations in which temporary coverage is required in:

- (a)Emergency / Disaster Recovery: The fixed infrastructure may have been destroyed.
- (b)Temporary Coverage for Event: In sporting game, military event or need fair requires that coverage provided for the duration of the event.

Typically, antenna heights are relatively low, such as vehicle-mounted masts, and need quick deployment and fast tear-down due to unanticipated environmental anomalies or deployment dynamics. The channel conditions between MMR-BS and RSs can be expected LOS or NLOS.

#### (4) Coverage on mobile vehicle usage model

In this usage model coverage is provided for user devices which are moving together on a mobile vehicle, such as a bus, a train or ferries. A mobile RS is fixed in the vehicle and it connects to an MMR-BS or RS through a mobile link. Then the RS provides a fixed access link to MS/SS devices. RSs deployed in this usage model are expected to be complex. Antenna heights would be significantly lower than the fixed and nomadic deployments due to vehicular restrictions and operational safety concerns. Mobile relay in this model may have severe size, weight, and power limitations.

## 2.3 Overview of the Physical Layer

In traditional network, the Base Station and User Terminal were connection by wireless, then that was the “single-hop” network. The relay technology is between the Base Station and User Terminal will insert one or more Relay Station (RS). That mean the wireless signal will through “Two-hop” or “Multi-hop” to the User Terminal.

The operation frequency of IEEE802.16d standard [1] is distributed from 10-66GHz, which is line of sight (LOS) transmission, or 2-11GHz, which is non line of sight (NLOS) transmission. In the urban area, line of sight transmission is almost impossible due to the prevention of buildings. So to solve problems will focus on 2-11GHz PHY. There are three air interface defined in spec:

#### (1)WirelessMAN-SCa

This model uses a single-carrier modulated air interface.

#### (2)WirelessMAN-OFDM

It is a 256 carrier orthogonal frequency division multiplexing scheme. Multiple access mechanism is time division multiple accesses based.

#### (3)WirelessMAN-OFDMA

It uses orthogonal frequency division multiple access. Multiple accesses are provided by assigning a subset of the carriers to specific user. In 802.16e standard, the number of subcarriers could be 128, 512, 1024, and 2048. The standard supports two duplex methods: time division duplex (TDD) and frequency division duplex (FDD). In 802.16j the standard need to fit in with backward compatible.

In this thesis, the research adopts OFDMA PHY and TDD mode. So in the latter part, the introduction of this system will be focused on the OFDMA PHY, and the model of Relay Station (RS) operation, scheduling, frame structure, these can separate two part, one is “Transparent mode”, another is “Non-Transparent mode”.

### 2.3.1 Relay Station to operation model

Here have two kinds of relay operations: transparent relay (Figure 2-9) and non-transparent relay (Figure 2-10). RS shall work in one mode at one time. The relay operation mode can be configured during it’s network entry or network deployment [21].

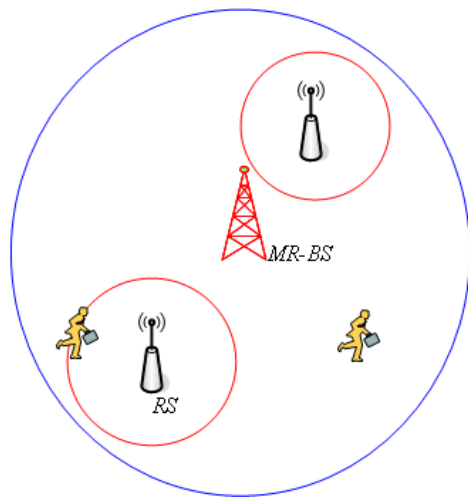


Figure 2-9 Transparent Relay

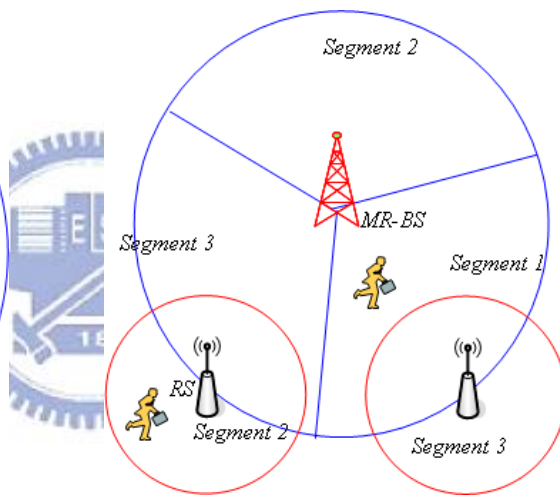


Figure 2-10 Non-Transparent Relay

#### 2.3.1.1 Transparent Relay

The operations, scheduling mode, frame structure of the characteristics of transparent Relay Station will be described in the following session.

##### 2.3.1.1.1 Operation

In transparent relay operation, MS associated with RS which is located in the coverage of Multihop relay base station (MR-BS), and the DL control signal from MR-BS can directly transmit to MS without RS relaying. MS will not recognize the existing of the RS even though MS communicates with the MR-BS via the transparent RS. Transparent Relay will be used to improve the poor radio link in the cell edge, coverage hole, dead spot, but it will not to extend the coverage as shown in Figure 2-9.

The total resource was controlled by the MR-BS. In this mode, the relay station (RS) got the radio signal from the Multihop relay base station (MR-BS), and it will estimate the channel condition of user terminal or the subordinate relay station(RS), and re-transmit it by appropriate modulation and coding schemes (MCS).

#### **2.3.1.1.2 Scheduling**

Transparent relay only supports centralized scheduling, and transparent relay is dedicated for throughput enhancement, where MS is located in the coverage of BS's broadcast information.

#### **2.3.1.1.3 PHY Frame Structure**

In the frame structure(Figure 2-11), Multihop relay base station (MR-BS) have it own transmit DL frame-start preamble, FCH, MAP messages or channel descriptor (DCD/UCD) messages, but Relay Station (RS) did not have. All MSs and RSs within one MR-cell are synchronized to MR-BS by its preamble, and get the resources allocations by DL/UL MAP.

**Preamble:** In the first symbol of frame structure is occupied by the preamble. The function of preamble is used for the synchronization and enables MSs to estimate the channel condition and correct frequency/time offset.

**Frame Control Header (FCH):** It consists of the DL\_Frame Prefix, and specifies the length of the DL\_MAP message that immediately follows the DL\_frame\_Prefix and the repetition coding used for the DL-Map message.

**DL-MAP and UL-MAP:** They completely describe the contents of the DL and UL subframe. The DL-MAP and UL-MAP allocate the resource for DL and UL data bursts, which include what bursts belong to MS. Besides, modulation and coding schemes (MCS) per burst are indicated by the Downlink Interval Usage Code (DIUC) and Uplink Interval Usage Code (UIUC). In the UL-MAP, it also grants bandwidth to specific MSs. Therefore, MSs can transmit data in their assigned uplink allocation. The DL and UL bursts are use for data transmission of different users.

**Ranging subchannels** are dynamically allocated by the MAC layer and indicated in the UL-MAP. The ranging subchannel has three major functions: (a) Initial ranging: It is used by any MS when it wants to synchronize to the system channel for the first time. (b) Periodic-ranging: It is used for periodically updating system time and power. (c) Bandwidth request: It is used for requesting uplink allocations from the BS.

**Transmit/receive transion gap (TTG)** is a gap between the downlink burst and the subsequent uplink burst. It gives the time for the BS switches the state of transmit to receive mode and MSs to switch from receive to transmit mode.

**RS transmit/receive transion gap (R-TTG)** is the minimum transmit to receive turnaround gap required at an RS. It is measured from the time of the last sample of

the transmitted burst to the first sample of the received burst at the antenna port of the RS.

**Receive/transmit transition gap (RTG)** is a gap between the uplink burst and subsequent downlink burst. It allowed the time for the BS to switch the state of receive to transmit mode and MSs to switch from transmit to receive mode.

**RS receive/transmit transition gap (R-RTG)** is minimum receive to transmit turnaround gap required at an RS. It is measured from the time of the last sample of the received burst to the first sample of the transmitted burst at the antenna port of the RS.

**DL access zone:** A segment of the DL sub-frame in the MR-BS/RS frame used for MR-BS/RS to MS or transparent RS transmission. The DL access zone may consist of the entire downlink subframe, depending on the method used to separate the transmissions on the access and relay links.

**DL relay zone:** A segment of the DL sub-frame in the MR-BS/RS frame used for MR-BS/RS to RS transmission. A frame may have no DL relay zone, depending on the method used to separate the transmissions on the access and relay links.

**UL access zone:** A segment of the UL sub-frame in the MR-BS/RS frame used for MS to MR-BS/RS transmission. A frame may have no UL access zone, or the UL access zone may consist of the entire uplink subframe, depending on the method used to separate the transmissions on the access and relay links.

**UL relay zone:** A segment of the UL sub-frame in the MR-BS/RS frame used for RS to MR-BS/RS transmission. A frame may have no UL relay zone, or the UL relay zone may consist of the entire uplink subframe, depending on the method used to separate the transmissions on the access and relay links.

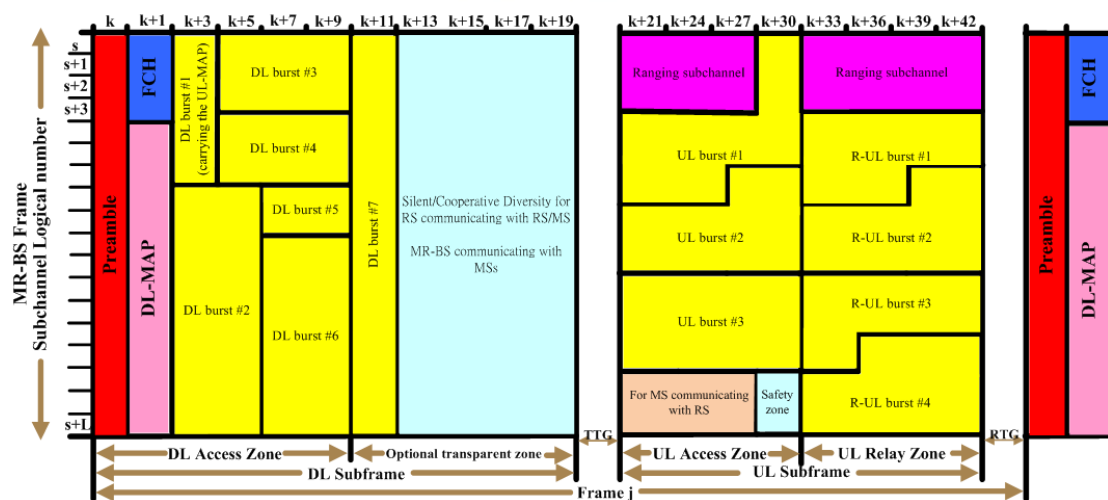


Figure 2-11 MR-BS frame structure configurations for a transparent relay station

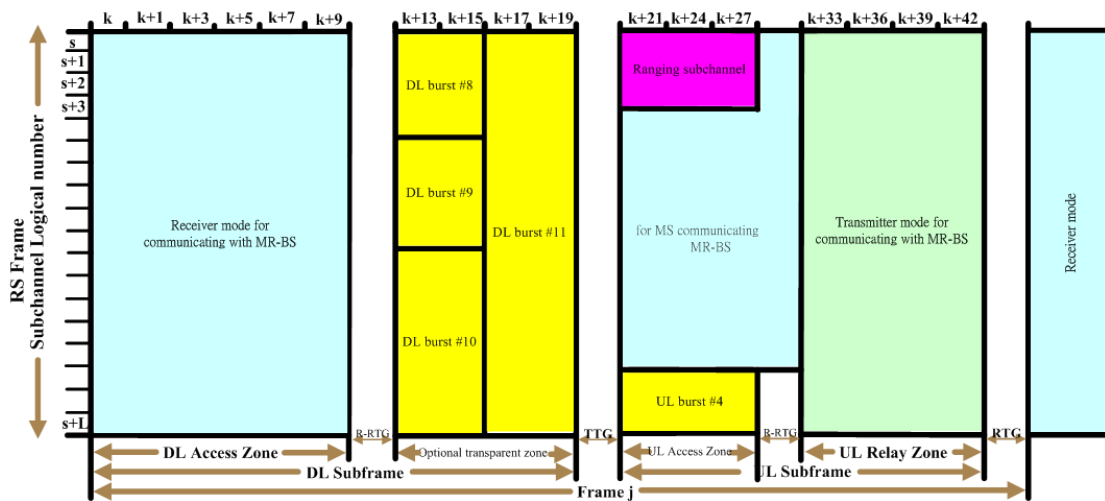


Figure 2-12 RS frame structure configurations for a transparent relay station

### 2.3.1.2 Non-Transparent Relay Operation

The operations, scheduling mode, frame structure of the characteristics of non-transparent Relay Station will be described in the following session.

#### 2.3.1.2.1 Operation

Non-transparent Relay is to increase the cell coverage (Figure 2-10). In this mode the non-transparent relay station (RS) can allocate the partial resource to the user terminal or the subordinate relay station (RS). All data and control signal transmission between MR-BS and MS are relayed. It can reduce the Multihop relay base station (MR-BS) loading and optimize the system performance, but Non-transparent Relay will be more complex than Transparent Relay. Transparent RS and non-transparent RS can coexist in one MR-cell.

#### 2.3.1.2.2 Scheduler

The non-transparent RS may support centralized scheduling or distributed scheduling. The centralized scheduling RS does not create its own DL/UL MAP but may modify the MAP from MR-BS if necessary. As a contrast, the distributed scheduling RS generates its own DL/UL MAP.

#### 2.3.1.2.3 PHY Frame Structure

The Multihop relay base station (MR-BS) and the non-transparent relay station (RS) transmit its own frame messages (Figure 2-13, Figure 2-14). When the non-transparent RS used centralized scheduler; the MR-BS will determine the transmission parameters and allocation for DL/UL access zone and relay zone of MR-BS and RS frame.

The transmission parameters and allocation information include FCH, DL/UL MAP for access zone, R-FCH, R-MAP and for relay zone, the access zone and relay zone was belonged to the frame of MR-BS. The first transmitted relay zone in the downlink shall include an R-FCH and an R-MAP. When non-transparent RS receives these transmission parameters and allocation information, RS shall transmit FCH, DL/UL MAP in DL access zone, and the RS forward the scheduling information for other RSs in the relay path in DL relay zone the function like the MR-BS. Other intermediate RSs shall do the same operation as the first RS. And the access RS only broadcasts FCH, DL/UL MAP in DL access zone as indicated by the received scheduling information from super ordinate RS or MR-BS.

The MR-BS has to do the scheduling for non-transparent RS with centralized scheduler. In every frame duration time, RS needs to schedule MAP message which contains all the scheduling and configuration information, it had a very large overhead.

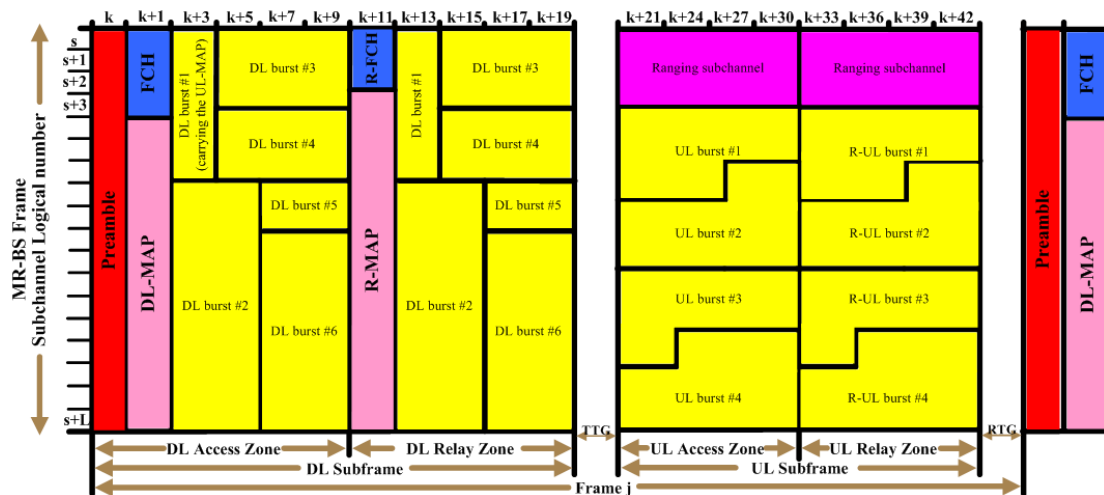


Figure 2-13 MR-BS frame structure configurations for a non-transparent relay station

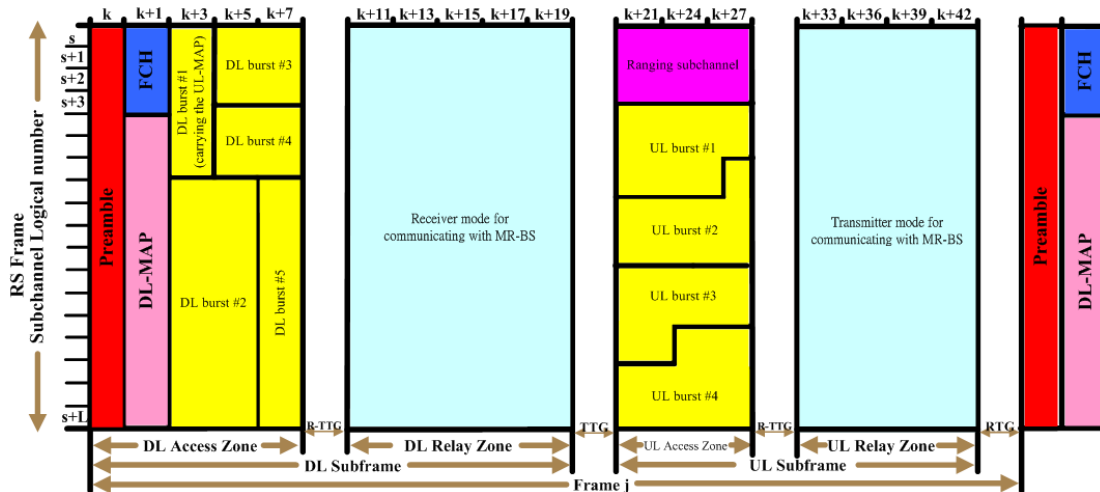


Figure 2-14 RS frame structure configurations for a non-transparent relay station

### 2.3.2 PHY Slot and Data Mapping

The OFDMA slot is a minimum unit for system data transmissions. One OFDMA slot occupies one subchannel and several OFDMA symbols. Here has four subchannel allocation performed in the following ways:

- (a) Downlink Full Usage of Subcarriers (FUSC) using the distributed subcarrier permutation, one slot is one subchannel by one OFDMA symbol.
- (b) Downlink Partial Usage of Subcarriers (PUSC) using the distributed subcarrier permutation, one slot is one subchannel by two OFDMA symbols.
- (c) Uplink PUSC using either of the distributed subcarrier permutations, one slot is one subchannel by three OFDMA symbols.
- (d) Uplink and Downlink Band Adaptive modulation and coding (Band AMC) using the adjacent subcarrier permutation. One slot is one subchannel by one, two, three, or six OFDMA symbols.

All the allocation refers to logical subchannels. A data region is a two-dimensional allocation which contents a group of contiguous subchannels and OFDMA symbols. The minimum unit of data mapping is an OFDMA slot. Based on standard, how many resource units would be assigned to a transmission is decided by BS and the mechanism is different in downlink and uplink transmission. In downlink resource allocation, system will consider the data size and try to enforce the resource units first in frequency domain. After the frequency domain is enforced, then it goes to the next time domain to enforce resource units. (Figure 2-15)



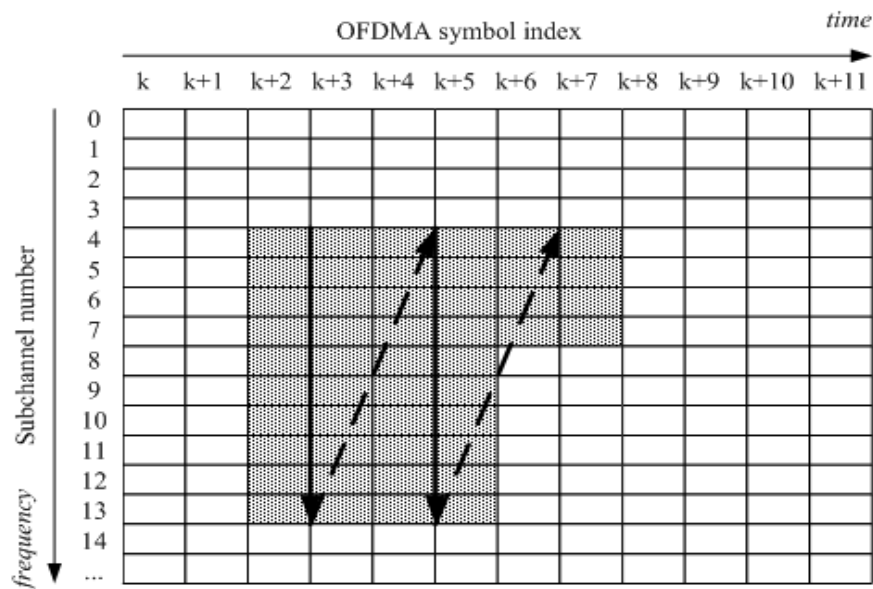


Figure 2-15 OFDMA slots to subchannels and symbols in the downlink PUSC mode

In uplink resource allocation, when uplink resource allocation will try to enforce resource units in time domain, after the time domain resource units are full, then go to another frequency domain and repeat the procedure. (Figure 2-16)

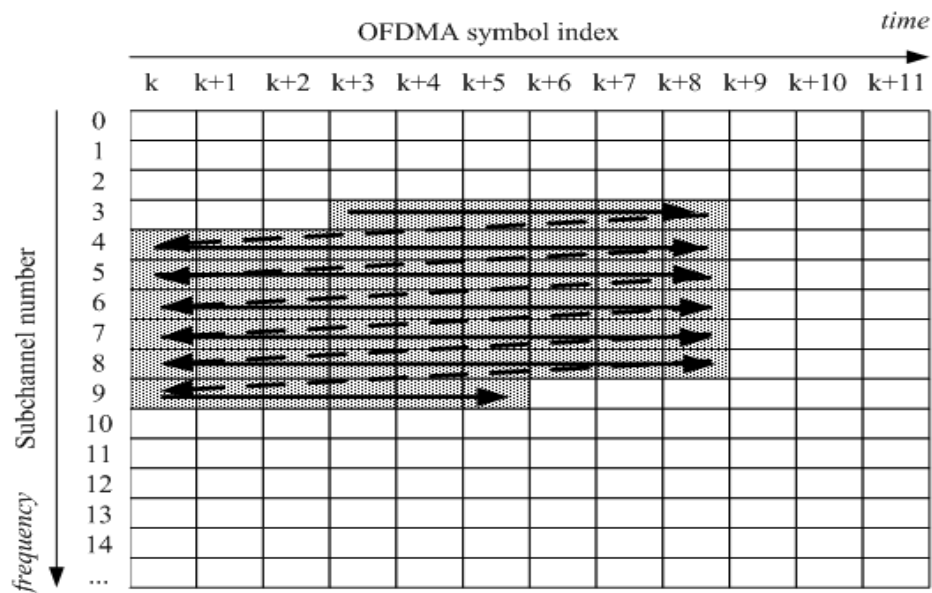


Figure 2-16 OFDMA slots to subchannels and symbols in the uplink PUSC mode

### 2.3.3 Subcarrier Permutation

Subcarrier permutation is a method to assign frequency subcarriers into subchannels. The allocation of subcarriers to subchannels is accomplished via permutation rule. There are two kinds of permutation modes:

(a) Distributed subcarrier permutation: The subcarriers belonged to a subchannel are selected pseudo randomly from all subcarriers. It can average inter-cell interference and avoid fading effect.

(b) Adjacent subcarrier permutation: The subchannel whose subcarriers coming from adjacent subcarriers. In this method, system can take advantage of frequency select fading and get multiuser diversity form frequency domain.

IEEE802.16 standard provides three ways to group subcarriers into subchannels:

(a) Full Usage of Subchannels (FUSC)

This method is only used in downlink and can use all subcarriers to do permutation for one subchannel. It can achieve the best frequency diversity by spreading subcarriers over entire band.

(b) Partial Usage of Subchannels (PUSC)

This method can be used both in downlink and uplink. It will group subcarriers first then choose subcarriers per group and each group only provides one subcarriers to form a subchannel.

(c) Band Adaptive Modulation and Coding (Band AMC)

This method can be used both in downlink and uplink. It uses adjacent permutation mode. The bandwidth is divided into sub-band and tries to utilize the frequency select fading to enhance system performance.

### **2.3.4 Adaptive Modulation and Coding (AMC)**

IEEE802.16e system is able to adjust modulation coding scheme depends on the carrier to interference plus noise ratio (CINR) condition of the radio link. IEEE802.16 OFDMA architecture supports multiple modulation methods: Quadrature Phase Shift Keying (QPSK), 16-state Quadrature Amplitude modulation (16-QAM), and 64-state Quadrature Amplitude modulation (64-QAM). It can adjust dynamically to trade off the efficiency and the robustness. The OFDMA architecture can support several coding schemes, like Convolution Code (CC), Convolution Turbo Code (CTC), Low Density Parity Check Code (LDPC), and Block Turbo Code (BTC).

### **2.3.5 Relaying techniques**

In relaying technique, the signal goes through a single multi-hop path formed by relays between the source and destination. About the relaying technique, there are four possible technologies:

(a) Amplify and Forward (AF)

(b) Decode and Forward (DF)

(c) Compress and Forward (CF) [22]

(d) Estimating and forwarding (EF) [23]

(a) Amplify and Forward (A&F): The function is like the analog repeaters; relay will amplify the signal and retransmits it to the destination. The signal might aggregate of relay link fading and additive receiver noise. The degraded signal and noise are amplified and forwarded, thereby increasing the system noise level.

(b) Decode and Forward (D&F): The function is like the digital repeaters (or call layer 2 relays). The relay demodulates and decodes the received signal before forwarding it to the destination.

(c) Compress-and-Forward (C&F): It also known as Quantize and Forward Q&F [24]. C&F is the relay quantizes the signal when it received from the source and encodes the samples into a new packet which is forwarded to the destination, so that the latter can combine the two observations.

(d) Estimating and forwarding (E&F): The relay does not decode the input data, but it re-encodes the received signal (after quantization) and transmits it to the destination. In this case the forwarded signal contains possible estimation errors. The destination uses the relay estimation as side information when coding the actual direct link signal. The most popular of relaying techniques is decoded and forward (D&F). In [25][26], the performance analysis was show the decoded and forward (D&F) techniques have the better bit error rate (BER) then Amplify and Forward (A&F) in same SINR (Signal to Interference plus Noise Ratio).

## 2.4 Overview of the Medium Address Control Layer

In Open Systems Interconnection Basic Reference Model (OSI Reference Model or OSI Model), the Data Link Layer can separate two sublayers: Media Access Control (MAC) and Logical Link Control (LLC). The MAC layer connects with the Physical layer and manages the interaction of devices with a shared medium. Above MAC Layer and under Network Layer is the LLC sublayer, which deals with addressing and multiplexing on multi-access media.

The MAC layer of the system will process several tasks, and keep the system efficient. IEEE802.16 was designed for point to multipoint (PMP) broadband wireless access applications and is a connection-oriented system. It is designed to meet the needs of the very high data rate application with a variety of quality of service (QoS) requirement on both uplink and downlink. The MAC layer must manage the radio resource to decide how to let users access the resource, handoff users when they are going to leave the cell coverage, decides whether to let users register into the system, to do power control or rate control, etc. The MAC layer protocol is flexible and efficient over a wide range of different data traffic models. The radio resource management is an important issue should be done to maintain the QoS requirement

which is also implemented in this layer. The MAC layer must integrate the information from upper layer and Physical layer. It should know the traffic QoS requirement to allocate suitable resource to users. It will do retransmission if Physical reflects there is error occurs before the transmission. It should fragment and packet the data unit to avoid transmission error occurs or transmission inefficient.

### 2.4.1 802.16e MAC structure

In IEEE802.16 system, the MAC layer is divided into three sublayer and all of them have their own functionality as show in figure2-17.

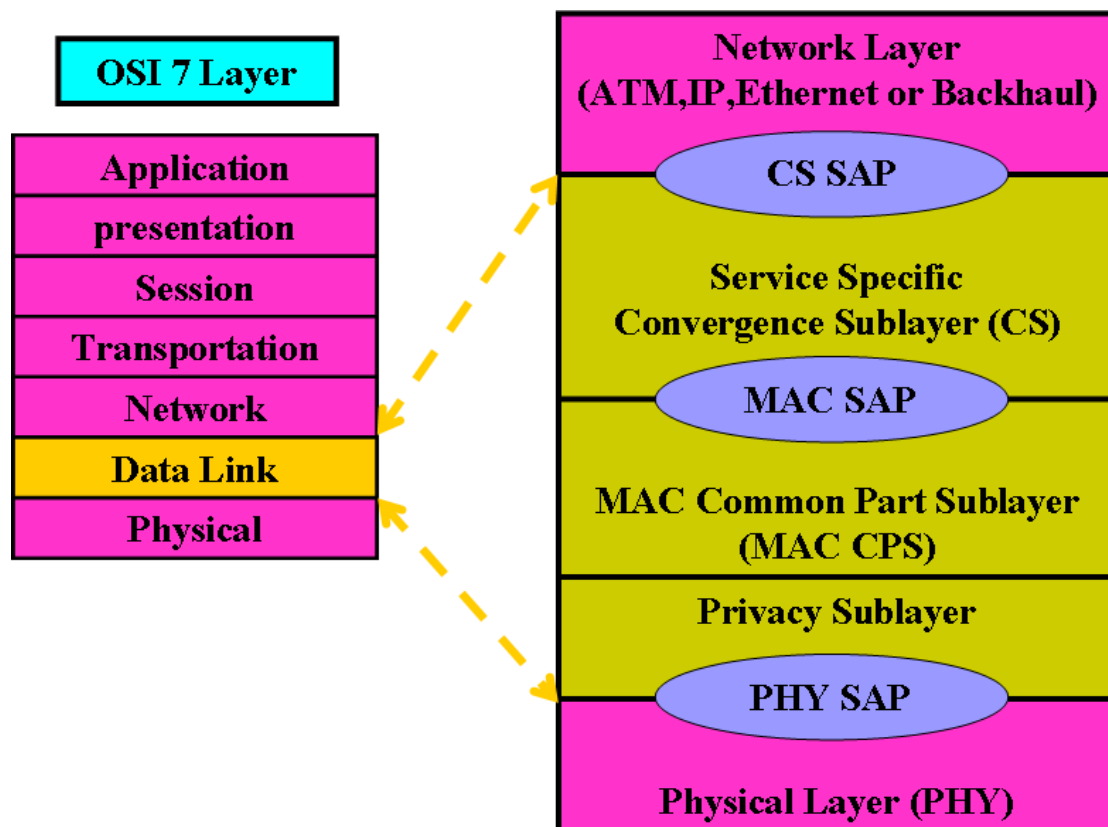


Figure 2-17 IEEE 802.16 protocol layer

#### (a) Service-Specific Convergence Sublayer (CS)

This sublayer is an interface between upper layer and MAC layer. It will identify different traffic from upper layer and assign connection ID (CID) to each connection and classify service data units (SDUs) to the proper MAC connection. It also provides payload header suppression and reconstruction to enhance the air link efficiency.

#### (b) Common Part Sublayer (CPS)

The Common Part sublayer manages the main function of controlling the whole radio resource. It was about the QoS control, fragmentation and packing, scheduling, request-and-grant, admission control, handover, and ARQ will be controlled in this sublayer. Besides, segmentation of SDU into MAC PDU (protocol data unit) is also implemented in this sublayer.

(c) Security Sublayer

In multihop relay system, RS uses the same security architecture and procedures as an SS to provide privacy, like the authentication of network access, registration, key exchange, and encryption of PDUs and confidentiality between itself and the MR-BS. MR-BS and a group of RSs in MR cell maintain a set of trusted relationships, called Security Zone, in order to satisfy requirements of multi-hop relay system operation.

### 2.4.2 MAC PDU Formats

The MAC PDU is a data exchanged unit between the MAC layer of the BS and MSs. The maximum length of the MAC PDU is 2048 bytes, including header, payload, and CRC. A MAC PDU consists of a 48bit MAC header, a variable length data payload, and an optional 32 bits Cyclic Redundancy Check (CRC). There are two types of MAC headers: Generic MAC header and Bandwidth request MAC header. The MAC PDUs include some subheaders. Here was the MAC PDU subheader : 1. Grant management subheader. 2. Fragmentation subheader. 3. Packing subheader. These MAC subheaders include the bandwidth request, uplink transmit power report, CINR report, CQICH allocation request, PHY channel report, uplink sleep control, SN report, and feedback functionalities, etc.

### 2.4.3 Fragmentation and Packing

In 802.16e system, MAC SDUs coming from Service-Specific Convergence Sublayer(CS) will be formatted according to the MAC PDU format in the Common Part Sublayer (CPS), possibly with fragmentation and packing. The fragmentation and packing process can utilize the bandwidth allocation more efficiently.

The fragmentation subheader indicates the presence and orientation in the payload of any fragments of SDUs. The process divided a SDU into different PDUs payload areas, because the maximum MAC PDU size is limited in 2048 bytes, and larger PDU size may causes error occurs more easily. Therefore, divide SDU properly according to the channel condition will avoid transmission errors and save the resource. Figure 2-18 shows the process of fragmentation.

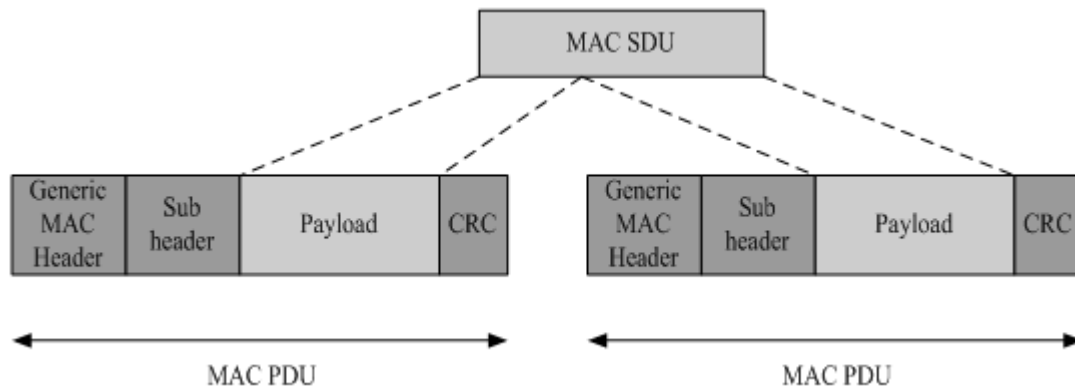


Figure 2-18 Fragmentation

The packing subheader is used to indicate the packing of multiple SDUs into a single PDU. Packing process is to pack several SDUs into a single PDU payload. In this way, system may avoid resource waste due to the overhead caused by MAC header and CRC. Figure 2-19 shows the process of packing. Both processes may be initiated by either a BS for a downlink connection or a MS for and uplink connection.

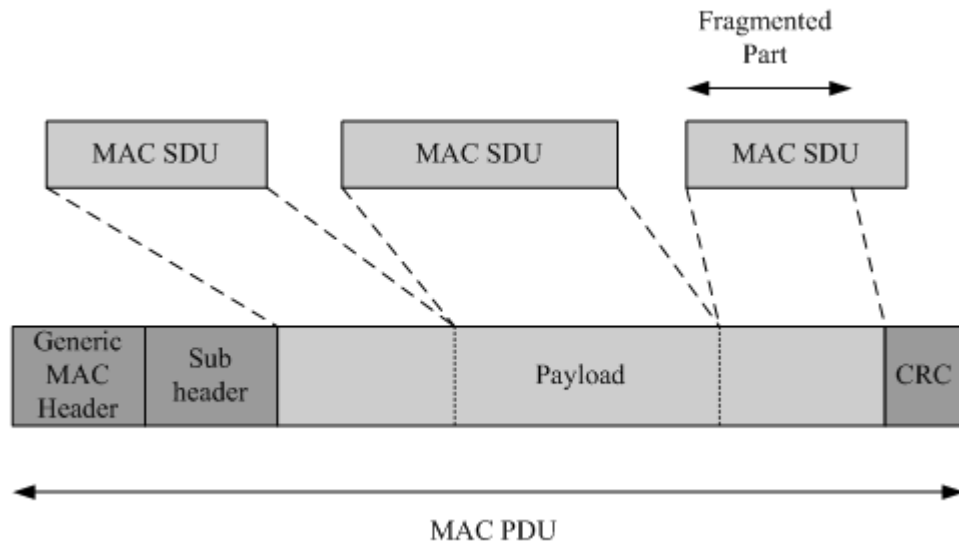


Figure 2-19 Packing

#### 2.4.4 ARQ

In [1][2][21][27], the Automatic Retransmission request (ARQ) can request the retransmission of part of a SDU. The ARQ mechanism is a part of the MAC, which is an optional function. A connection can not have a mixture of ARQ and non-ARQ traffic, and the ARQ mechanism is limited to one unidirectional connection. A MAC SDU is logically partitioned into ARQ blocks whose length is specified by the connection TLV (type/length/value) parameter, “ARQ\_BLOCK\_SIZE” and MAC PDU which is formatted by integer number of ARQ blocks is shown in Figure2-20.

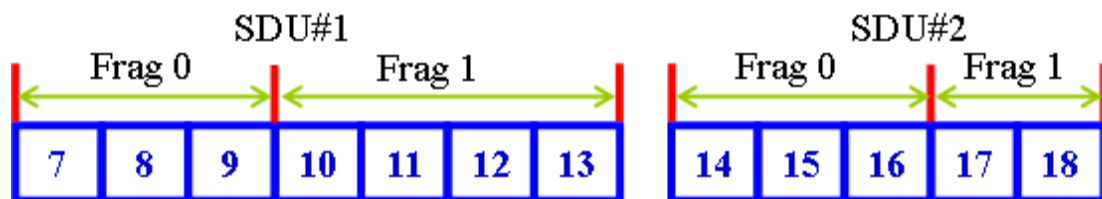


Figure 2-20 Two consecutive SDUs presented to MAC for the same connection

Once an SDU is partitioned into a set of blocks, partitioning remains in effect until all blocks of the SDU are successfully delivered to the receiver, or the SDU is discarded by the transmitter state machine. The receiver sends acknowledgement (ACK) or negative acknowledgement (NAK) messages to indicate the transmitter which ARQ

block of the PDUs have successfully been received or which have been lost. For instance, if the Figure2-21 PDU#1 was successfully delivered, but the PDU#2 was fail by transmission. The ARQ consist of two mechanisms, which is (a) With rearrangements and (b) Without rearrangements of blocks.

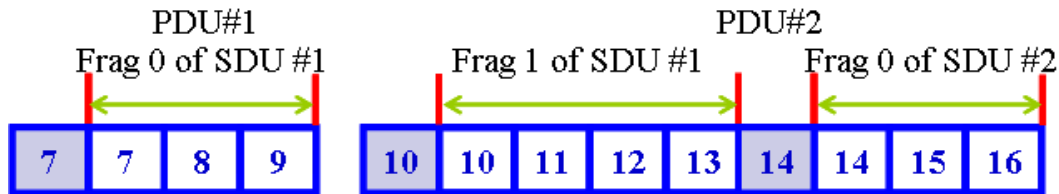


Figure 2-21 Original transmission

(a)With rearrangement, if the ARQ blocks of one PDU need to be retransmitted, it will be divided into different PDUs which share the blocks like the Figure2-22 can be change to two retransmitted PDUs .

(b)Without rearrangements, if any block of one PDU need to be retransmitted, the transmitter will retransmit all ARQ block of this PDU like the Figure2-23.

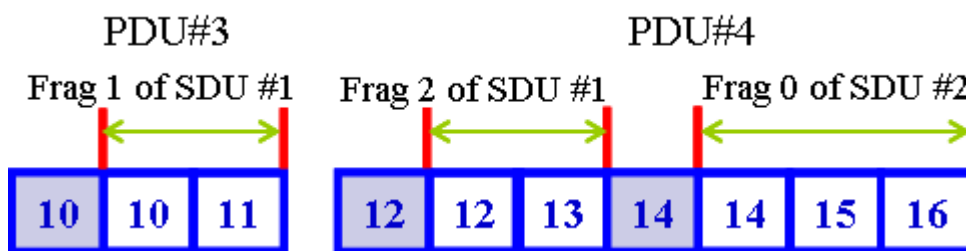


Figure 2-22 Retransmission of PDU #2 with rearrangement

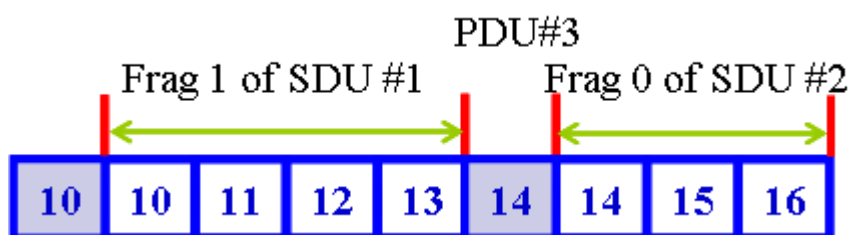


Figure 2-23 Retransmission of PDU #2 without rearrangement

In the Mobile Multihop Relay System (MMR), the ARQ mechanisms were consisting of three modes: (1) End-to-End ARQ mode. (2) Two-link ARQ mode. (3) Hop-by-Hop ARQ mode.

(1) End-to-end ARQ mode: The ARQ operation is performed between an MR-BS and an MS, which is same as original IEEE802.16d/e. An RS doesn't have an additional ARQ functionality.

(2) Two-link ARQ mode: The ARQ operation is divided into two links. Performed both between relay link (MR-BS and access RS) and between access link (RS and MS). The MR-BS schedules retransmission to access relay station when ARQ block or TDU (tunnel data unit) is corrupted in the relay link. The RS schedules retransmission to MS when ARQ block is corrupted in the access link. When an intermediate RS exists between MR-BS and access RS, it just forwards the ARQ block and ARQ feedback information between MR-BS and access RS. ARQ operation between access RS and MS is same as original IEEE802.16d/e.

(3) Hop-by-hop ARQ mode: Performed between each adjacent station and the intermediate RSs are involved in the ARQ operation. Two adjacent stations could be MR-BS, RS or MS. The support of ARQ mode is performed during the RS network entry. ARQ operation between access RS and MS is same as original IEEE802.16d/e. When TDU is corrupted in the relay link, the subordinate RS sends back R-NAK, and the MR-BS/super-ordinate RS schedules the retransmission of TDU to the subordinate RS. Then the MR-BS receives R-ACK from the subordinate RS, it waits for an ACK from the MS relayed by the intermediate RSs. Access RS may modify the ARQ feedback IE received from MS to indicate the ACK information to MR-BS. After MR-BS receives ACK from MS or super-ordinate RS receives R-ACK from the sub-ordinate RS, it clears the buffer corresponding to ARQ blocks. For superordinate RS, it clears the buffer corresponding to TDU after receiving R-ACK from the sub-ordinate RS.

Two-link ARQ is applicable in both tunnel and non-tunnel based forwarding while hop-by-hop ARQ is applicable in only tunnel-based forwarding mode. These modes are supported when RS is enabling on distributed scheduling mode with distributed security.

In [21][27], the Hybrid Automatic Repeat request (HARQ) scheme is an optional function of the MAC and can be enabled on a per-terminal basis. A burst can not have a mixture of HARQ and non-HARQ traffic. There are many variations on retransmission methods for HARQ, the most popular of HARQ are (1) Incremental Redundancy (IR) (2) Chase Combining.

(1)IR: The PHY layer will encode the HARQ packet to generate several versions of encoded subpackets. Each subpacket shall be uniquely identified by using a subpacket identifier (SPID).

(2)Chase Combining: The PHY layer shall encode the HARQ packet generating only one version of the encoded packet. As a result, no SPID is required for Chase Combining.

For downlink HARQ operation, the BS will send a version of the encoded HARQ packet. The SS will attempt to decode the encoded packet on this first HARQ attempt.



If the decoding succeeds, the SS will send an ACK to the BS, but if the decoding fails, the SS will send a NAK to the BS. In response, the BS will send another HARQ attempt. The BS may continue to send HARQ attempts until the SS successfully decodes the packet and sends an acknowledgement.

Two implementations of HARQ are supported: (1) Per-terminal: HARQ is enabled for all active CIDs for a terminal, and (2) Per-connection: it can be enabled on a per CID basis by using the DSA/DSC messages. The two implementation methods shall not be employed simultaneously on any terminal. If HARQ is supported, the SS shall support per-terminal implementation, and the MS shall support per-connection implementation. One or more MAC PDUs can be concatenated and an HARQ packet formed by adding a CRC to the PHY burst.

The HARQ mechanisms are describe in [28][29][30] for the Mobile Multihop Relay System (MMR). In [28][29], it have the elementary architecture, which discloses the HARQ category, and how to reuse the Channel Quality Indicator Channel (CQICH) indexed. In [30], it was defined that the main HARQ architecture which in the Transparent mode and Non-Transparent mode.

#### **2.4.5 QoS based service classes**

The IEEE802.16 provides several Quality of Service (QoS) classes for system supports different kinds of service. For different classes, system sets different parameters and transmission/request methods to let system maintain the QoS requirement for different kinds of service [31].

In downlink, it has four kinds of QoS classes:

(a)Real-time CBR data streams

The service is designed to support real-time service flows that generate fixed-size data packets on a periodic basis, such as T1/E1 and VoIP without silence suppression.

(b)Real-time VBR data streams

The service is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as moving pictures experts group (MPEG) video.

(c)Delay-tolerant VBR data streams

The service is designed to support delay-tolerant data streams consisting of variable-sized data packets for which a minimum data rate is required, such as FTP.

(d)Best effort data streams

The service is designed to support data streams for which no minimum service level is required and therefore may be handled on a space-available basis.

In uplink, it has five kinds of QoS classes.

(a)Unsolicited Grant Service (UGS)

The UGS is designed to support real-time service flows that generate fixed-size data packets on a periodic basis, such as T1/E1 and VoIP without silence suppression.

(b)Real-time Polling Service (rtPS)

The rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as moving pictures experts group (MPEG) video.

(c)Extended Real-time Polling Service (ertPS)

Extended rtPS is a scheduling mechanism which builds on the efficiency of both UGS and rtPS. The Extended rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as Voice over IP services with silence suppression.

(d)Non-real-time Polling Service (nrtPS)

The nrtPS is designed for non-real-time service which can tolerate more delay, such as FTP, web-browsing, etc.

(e)Best Effort Service (BE)

BE service is with the lowest QoS level. These kinds of service are designed to support data streams for which no minimum service level is required and therefore may be handled on a space-available basis.

## 2.4.6 Request and Grant Mechanism

The request and grant mechanism for different QoS classes will be different, this is because the characteristics and requirement are different.

In downlink, it is much easier to handle these procedures, because the BS has the precise information about traffic requirement. Therefore, BS can easily give bandwidth to downlink traffic. It's no need to do request and grant.

In uplink, it is more complicated to do request and grant. Requests refer to the mechanism that MS uses to indicate BS that they need uplink bandwidth allocation. The bandwidth request message may be transmitted during any uplink allocation, except initial ranging interval. A transmitted bandwidth request header will indicate the size of opportunities to be requested. The bandwidth request message could be transmit through polling mechanism. Polling is the process that the BS allocates to the MS bandwidth specifically for the purpose of bandwidth requests. After BS receives bandwidth request message, if there is additional bandwidth, BS will grant corresponding bandwidth to MS based on their request.

## 2.4.7 Handover

Handover mechanism handles mobile station switching from one base station to another. There are two basic types: soft handover and hard handover.

In soft handover, it is used in voice-centric cellular networks such as GSM or CDMA system. It uses a make-before-break approach whereas a connection to the target BS is

established before a MS leaves an ongoing connection to a BS. When used for non-real-time data traffic (Hypertext Transmission Protocol, File Transfer Protocol), soft handover will result in lower spectral efficiency because this type of traffic is burst and does not require continues handover from one BS to another.

In hard handover, connectivity with a BS is ended first before MS switches to another BS. This is a break-before-make approach. Hard handover is more bandwidth efficient than soft handover, but it causes longer delay.

In Relay system, there are two handover scenarios: (1) Intra- virtual cell (VC) handover: In Intra-VC handover, MS will not be aware the mechanism so the mechanism can be performed by resource allocation procedure. (2) Inter- virtual cell (VC) handover: Inter-VC handover procedure needs to communicate with MR-BS to another. Therefore, the MS will be aware the process. In the implementation complexity and the backward compatibility points of view, decentralized intra-VC handover and centralized inter-VC handover would be a preferred handover solution for 802.16j [32].



# CHAPTER 3

## SIMULATION SETUP

In this chapter, the IEEE 802.16j system level simulation platform will be described. The details of system architecture and simulation parameters are going to be explained. Then, the Link Budget, such as path loss and shadow fading, is set to be referred for IEEE 802.16j standard. The basic radio resource management (RRM) is mentioned in this chapter, such as Adaptive Modulation and Coding (AMC), scheduling controls, handoff method, and the traffic models of simulation is showed in this chapter. Finally, simulation architecture is also introduced.

### 3.1 The architecture of mobility platform

In the simulation of a mobile relay system, interference is an important element that determines performance in real cellular system. The interference effects need to be considered into the simulation. Now building a multi-cell environment in the simulation platform in which the inter-cell interferences can be considered into the performance analysis. Hence, consider the two tier interference per cell, and there are nineteen cells in the platform in order to approximate the real cell coverage with a hexagon. The system structure in Figure 3-1, we can see only center cell have two tier interference cells, as the result, consider the wrap around BSs architecture (Figure 3-2) to meet the requirement of interference calculation. After wrap around, the statistic simulation result of nineteen cells will be more meaningful.

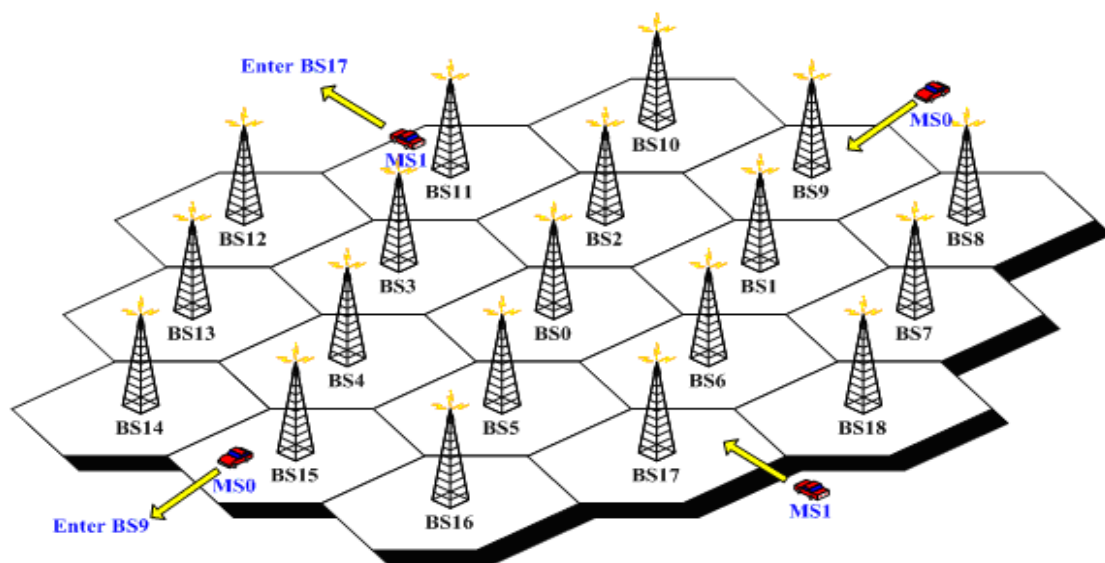


Figure 3-1 Cell structure of system simulation

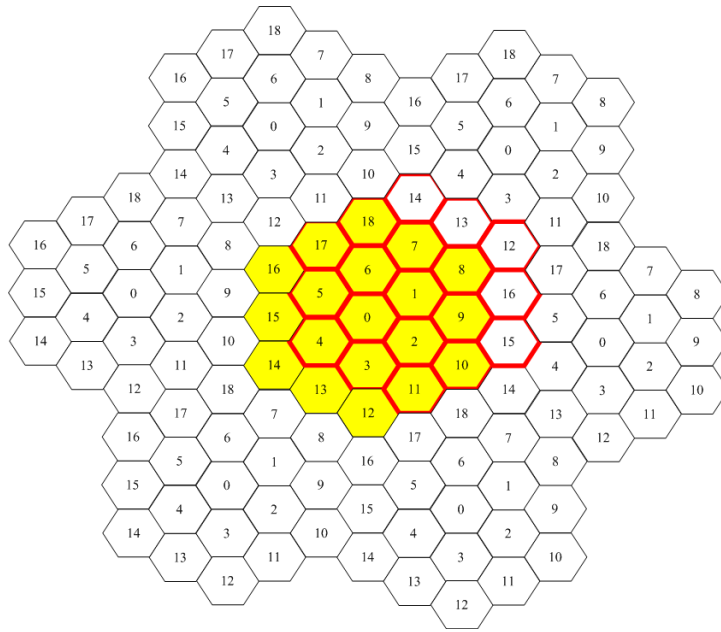


Figure 3-2 Example of Wrap around

The cell radius is set to 1 km [32]. This approximate cell coverage is a result from a plan of link budget. The total cell bandwidth is set to 10 MHz [1]. In the simulation platform, the three sectors per cell are adopted (Figure 3-3). In each sector, it has the different antenna direction and a regular pattern of deployment.

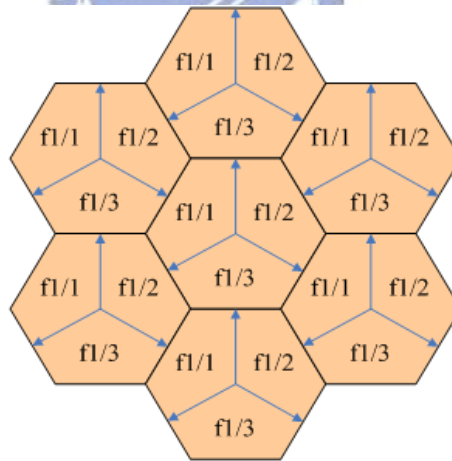


Figure 3-3 Example of sector deployment

In the simulation platform, the distance between the base station and relay station was  $\frac{2}{3}$  cell radius, and the angle between the two relay stations was used circumferential angle over the amount of relay stations. For example, the three relay stations deployment scheme were followed the base station antenna direction of the sector (Figure 3-4). The six relay stations deployment scheme were placed in the medium of the base station antenna direction and base station sector boundary (Figure 3-5). Regarding another number of relay stations like four, five, seven, eight, etc, those are

unfairness placement in sector's point of view. As a result of the issue, the placement scheme we only focused on three, six and nine relay stations.

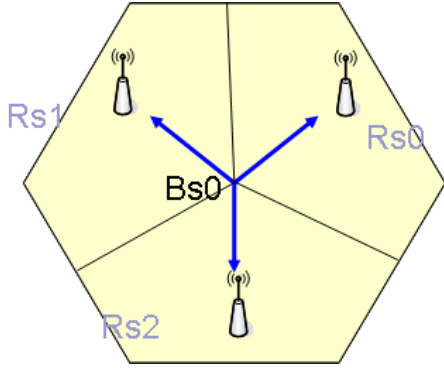


Figure 3-4 Example of 3RSs deployment.

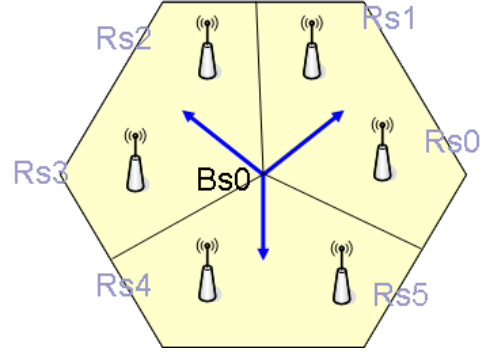


Figure 3-5 Example of 6RSs deployment.

Reuse factor 1 can be used in this simulation, and the deployment for reuse factor 1 is shown as Figure 3-6. If reuse factor 3 (Figure 3-6) was adopted, the total system bandwidth is three times of the reuse factor 1. Therefore, the total system bandwidth of reuse factor 3 is equal to 30 MHz.

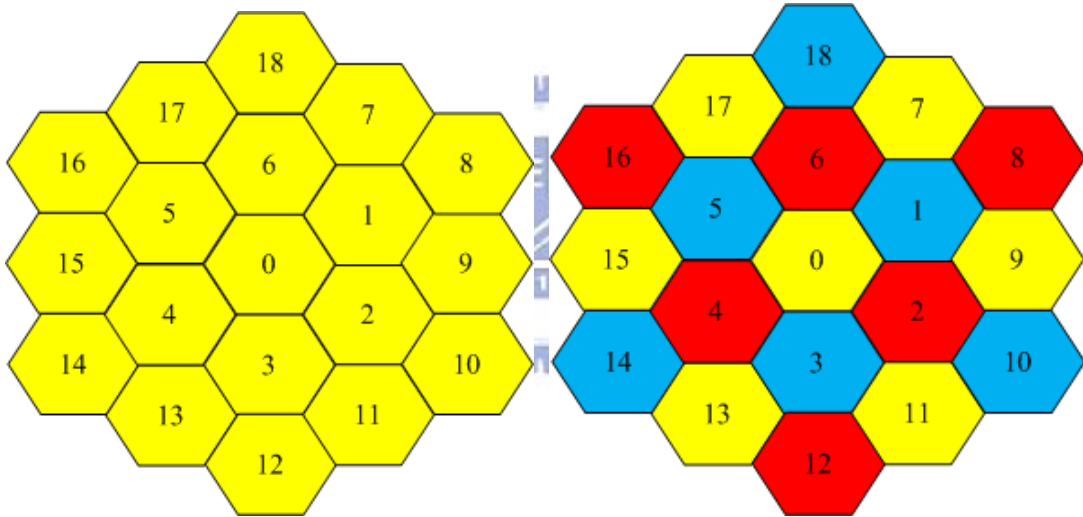


Figure 3-6 Cell plane for reuse factor 1 and 3

The setting of the antenna pattern is referred to 3GPP's model [33] as following.

$$A(\theta) = -\min \left[ 12 \left( \frac{\theta}{\theta_{3dB}} \right)^2, A_m \right], \text{ where } -180 \leq \theta \leq 180 \quad (3-1)$$

For 3 sector case: 120° antenna pattern,  $\theta_{3dB}$  is 70° ,  $A_m$  is 20 dB, and bore-sight gain is 3 dB, where  $\theta_{3dB}$  is the Azimuth radian 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.

The sector and relay stations architecture in IEEE802.16e/j system can reduce the transmission power of BS/RS antenna and inter-cell interference. The total bandwidth of a cell is divided equally into three parts, as the result, the intra-cell interference for sectors and relay stations are not need to be considered. But it still has a small part of inter-cell interference in different sectors and relay stations of distinct BSs caused by subcarrier permutation. This characteristic is very difficult to simulate, so the platform was assume a sector or relay station would produce interference to other sectors or relay station which have the same direction.

### 3.2 The architecture of frame transmission

In this thesis, the performance analysis focus on the downlink and it apply to OFDMA on PHY layer with TDD mode. The IEEE802.16j can support asymmetric access zone and relay zone in downlink and uplink transmission of TDD mode for which the system can adjust the ratio according to the traffic loading of downlink and uplink transmission.

The frame length in the simulation is set to 5 ms, and the frame structure we used is 1024-FFT OFDMA downlink carrier allocations – PUSC mode defined in the standard [1]. The carrier distribution is shown in Table 3-1. In the 1024 subcarriers, only 720 subcarriers carry data information and other subcarriers are used for guard band, pilot and DC subcarrier.

Table 3-1 1024-FFT OFDMA downlink carrier allocations with PUSC

Subcarrier types	Number
<b>Total subcarriers</b>	<b>1024</b>
<b>DC subcarriers</b>	<b>1</b>
<b>Guard subcarriers</b>	<b>92 (Left), 91 (Right)</b>
<b>Sub-channels</b>	<b>30</b>
<b>Data sub-carriers within each sub-channel</b>	<b>24</b>

The symbol length and the number of OFDMA symbols are define in WiMAX Forum [34][35]. In 10MHz bandwidth and 1024 FFT size, the symbol period should be 102.9  $\mu$ s and there will be 48 OFDMA symbols per frame. In our simulation, we assume it has the different ratio of downlink and uplink. It means that if we take off the overhead control message that included Preamble, FCH, Downlink map, Uplink map,

and we use PUSC, one slot is consisted of two/three symbols in downlink/uplink. As the result, 24 OFDMA symbols are assigned to downlink subframe, 18 OFDMA symbols are assigned to uplink subframe, 5 OFDMA symbols are assigned to the control message, and the last one is assigned to the TTG. Therefore, the resources will have 12 OFDMA slots for data transmission in every downlink subframe, and 10 subchannels per sector (30 subchannels /3 sector = 10).

To reduce the complexity of implement platform, we assume R-RTG (RS receive/transmit transition gap) was zero, that is signify that the base station can transmit the data to the relay station in the R-RTG. In the 12 OFDMA slots, we will divide two parts: 7 OFDMA slots for access zone, 5 OFDMA slots for relay zone. Hence, there will be 70 resource units per frame per sector (3 sector model) and 50 resource units per frame per relay station (3RSs model) to transmit data and messages. In 6 relay stations, it will allocate the half resources, which are 25 resource units per frame per relay station.

### 3.3 Link budge

The link budget settings of downlink transmission in our simulation are as far as possible to match the IEEE 802.16e/j real environment.

#### 3.3.1 Antenna parameter

In [32] [33][36], it makes deployments scenario assumptions for 802.16e/j, like Table 3-2. In our simulation we adopt the outdoor vehicular scenario, which the BS transmitted power is 46 dBm, the BS antenna gain is 17 dBi, the MS antenna gain is 3dBi on downlink transmission.

About the relay station setup, it was fix deploy in the simulation, so we adopt the outdoor to indoor condition, that is transmitted power is 36 dBm, the antenna gain is 17 dBi. And in IEEE802.16j Evaluation Methodology [36], the channel models need to consider the antenna height, like the BS antenna height is 30m, the RS antenna height is 15m. About the MS antenna height is 1.5m which was defined in [36].

The BS back off which is used to avoid the RF circuit working in the non-linear region due to the peak to average power ratio (PAPR) of OFDM system is 5dB. The common usage value of thermal noise density is -173.93dB/Hz[37]. The receiver noise figure of MS is 9dB [38].



Table 3-2 Link Budget Parameter of 802.16e/j system

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

### 3.3.2 Fading effect

In wireless channel, the transmitted signal will suffer the fading issue which might significantly cause distortion to the signal. The fading effect can be categorized into three types: path-loss, shadow fading, and fast fading (multi-path and Doppler effects). Path-loss and shadow fading are large scale fading, and fast fading belongs to small scale fading. In the simulation, we only consider the large scale fading: Path-loss and Shadow fading. The fast fading will be in the future works.

#### 3.3.2.1 Path loss

The path-loss mode is relative to the distance between transmitter and receiver. The increasing distance will cause the more attenuation of transmitted signal strength. In IEEE802.16j Evaluation Methodology [36], it provides several path-loss models as Table 3-3, and Table 3-4. In the simulation, the cell radius is 1km and the signal transmission in 2~11 GHz is non-line of sight (NLOS), and we also need to consider the relay station antenna placement in ART (Above Roof Top) or BRT (Below Roof Top). For this reason, we choose the two scenarios adopted in our simulation.

In BS to RS link is Type-D: Macro-cell suburban, ART to ART, LOS. In BS to MS link and RS to MS link are Type-E: Macro-cell, urban, ART to BRT, NLOS.

TABLE 3-3 SUMMARY TABLE OF PATH-LOSS AND SHADOW FADING STANDARD DEV TYPES FOR IEEE802.16J RELAY SYSTEM

Category	Transmission status	Description	Shadow fading standard dev
Type A	LOS/NLOS	Macro-cell suburban, ART to BRT for hilly terrain with moderate-to-heavy tree densities.	10.6
Type B	LOS/NLOS	Macro-cell suburban, ART to BRT for intermediate path-loss condition.	9.6
Type C	LOS/NLOS	Macro-cell suburban, ART to BRT for flat terrain with light tree densities.	8.2
Type D	LOS	Macro-cell suburban, ART to ART	3.4
Type E	NLOS	Macro-cell, urban, ART to BRT	8.0
Type F	LOS	Urban or suburban, BRT to BRT.	2.3
	NLOS		3.1
Type G	LOS	Indoor Office	3.1
	NLOS		3.5
Type H	LOS	Macro-cell, urban, ART to ART.	
Type J	NLOS	Outdoor to indoor	

TABLE 3-4 RELATIONSHIP BETWEEN PATH-LOSS AND USAGE MODELS

Links	Path-loss Type	Applicable Usage Model	Note
BS-RS	Type A/B/C	I, III, IV	Suburban, RS antenna is BRT
	Type D	I, III	BS antenna is ART and RS antenna is ART
	Type E	I, III, IV	Urban, BS antenna is ART and RS antenna is BRT
	Type H	I, III	Urban, BS antenna is ART and RS antenna is ART
	Type J	II	BS is outdoor and RS is indoor/tunnel
RS-RS	Type A/B/C	I, III, IV	Suburban, one RS antenna is ART
	Type D	I, III	Both RS antennas are BRT
	Type E	I, III, IV	Urban, One RS antenna is ART and another one is BRT
	Type F	I, III, IV	Both RS antennas are BRT
	Type G	II	Both RS antennas are inside building
	Type J	II	One RS is outside and the other inside a building/tunnel
BS-MS	Type A/B/C	I, III, IV	Suburban, BS antenna is ART
	Type E	I, III, IV	BS antenna is ART
	Type J	II	BS is outdoor and MS is indoor/tunnel
RS-MS	Type A/B/C	I, III	Suburban, RS antenna is ART
	Type E	I, III	RS antenna is ART
	Type F	I, III, IV	RS antenna is BRT
	Type G	II	Both RS and MS antennas are inside building
	Type J	II	RS is outside and MS is inside or RS is inside and MS is outside

Here, the usage models were already described in section 2.2.2 Relay Stations to Usage, those are:

- I . Fixed Infrastructure Usage Model
- II . In-Building Coverage Usage Model
- III. Temporary Coverage Usage Model
- IV. Coverage on Mobile Vehicle Usage Model

### 3.3.2.2 Shadow fading

The main reason for shadow fading is from the shelters situation in which there might be buildings, shelters, mountains on the transmission path. According to the test result of the real wireless environment, we could know the variance of shadow fading is a log-normal distribution statistically. The standard deviation of this distribution is

based on the simulation environment. In our simulation, we use 8dB for BS and RS to MS and 3.4dB for BS to RS for the standard deviation [36]. When the user is fixed, the shadow fading effect will not alter. On the other hand, the shadow fading changes with different locations at the mobile user. Since the simulation time between two time points is only 5ms. When the MS moved at the 30kmph, it only moved 4.17cm in every 5ms. It is too short to cause significant change of received signal strength for MS even in high mobility environments. It means that shadow fading must be correlative in consecutive simulation points. Hence, the correlation model, called Gudmundson's correlation model [39] is adopted. The formula of correlation model is shown as following.

$$\rho(\Delta x) = e^{-\frac{|\Delta x|}{d_m} \ln 2} \quad (3-2)$$

About the formula, the  $\rho$  is the auto-correlation constant between two simulation sample points,  $\Delta x$  is the distance of the two sample points and is a function of sampling times between them, sample duration, and user speed. The  $d_{cor}$  is de-correlation distance. The value in the suburban macro, urban macro, and urban micro environments are 200m, 50m, and 5m, respectively. In our simulation, we use 5m in our platform. In Figure 3-7, we present the flow of signal-to-interference and noise ratio (SINR) computation. In fact, we should compute carrier-to-interference and noise ratio (CINR) instead of SINR, but the MS of 802.16 systems with PUSC or FUSC mode only report the sum of received CINR of each subcarrier. Therefore, the SINR is equal to CINR under these conditions. The MS parameter about the mobility model is introduced as following. The MS speed is 30 km/hr probability to change direction is 0.2 when position update. The update time was by every frame length. Maximum angle for direction update is  $45^\circ$ .

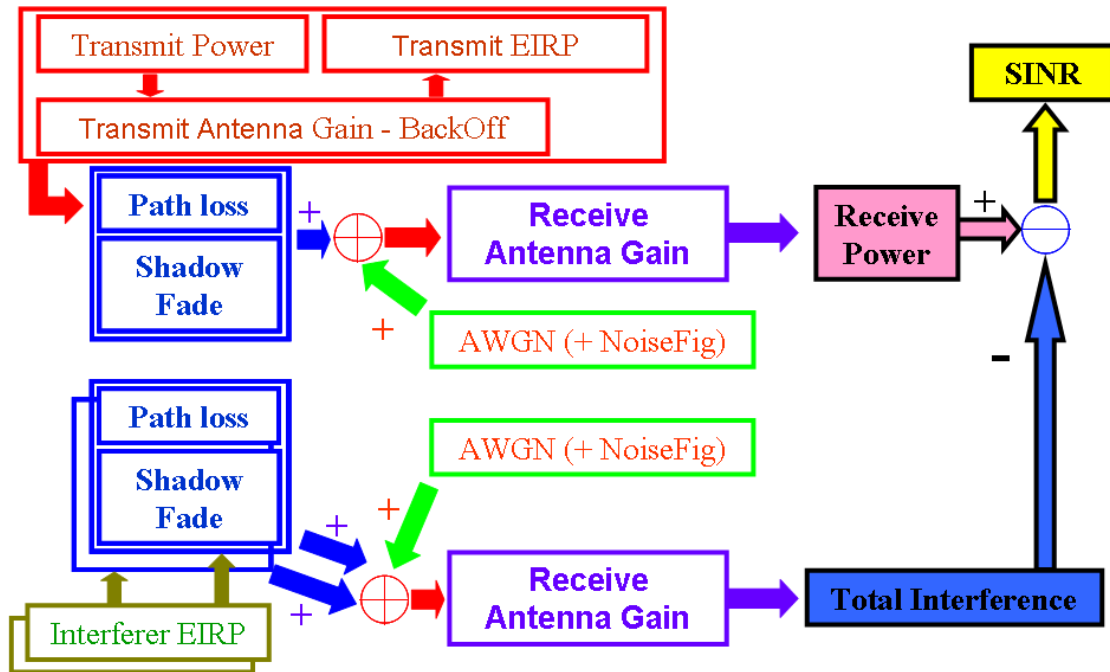


Figure 3-7 Example of SINR computation

### 3.4 Basic radio resource management

This section was purposed of RRM is to improve efficiency and guarantee QoS. In the performance analysis, the basic RRM controls are described as following.

**Power control:** The BS/RS transmit signal with maximum fixed power 46/36 dBm. The power of each subcarrier is the same.

**Rate control (AMC):** Adaptive Modulation Coding scheme is important to meet the required target bit error rate when transmitted power is fixed. In IEEE802.16 standard, only QPSK, 16-QAM, 64-QAM modulation schemes are available, and the coding scheme adopted in the platform is convolution code with 1/2 code rate. From standard, it can compute the carried bits per resource unit are 48, 96, 144 bits in order when using QPSK, 16-QAM, 64-QAM.

**Channel assignment:** The OFDMA resource units are two dimensional structures: frequency and time slot. The basic principle for downlink channel assignment in IEEE802.16 is frequency first. When resource allocation is performed, the subchannel will be assigned to a serving user first, if resource allocation in current slots were exhausted subchannels, then restart assignment from first subchannel of next time slot.

**Subcarrier permutation:** The distributed permutation is used in this platform. To reduce the complexity of simulation computation, we do not use the original permutation method. The approximated permutation is to dispread each interference resource units to the whole frame.

**Scheduling method:** In the platform, we only implement simple algorithm which is Round Robin, Proportional Fair, Early Deadline First, Max CINR. But we only apply EDF algorithm in our performance analysis.

**Handoff method:** In this thesis, handoff is not a weight-bearing point. So, Hard handoff is used. This method is “Break-Before-Make”.

**ARQ retransmission:** As mentioned in 2.4.4, simple BS/RS ARQ is implemented. The available maximum retransmission times were depending on different service. It had three times for HTTP and FTP service, and one time for VoIP. In the platform, we used the “End to End” model, but we still need to consider the two link probability of the error occur: BS to RS and RS to MS. The error PDU will be retransmitted before exceeding lifetime or retransmission time.

**Path selection:** In Figure 3-8, the relay station placement was to show how many path we can select. The user can get the signal from (1) BS only [R<sub>3</sub>], (2) Two hops [R<sub>2</sub>], (3) Three hops [R<sub>1</sub>].

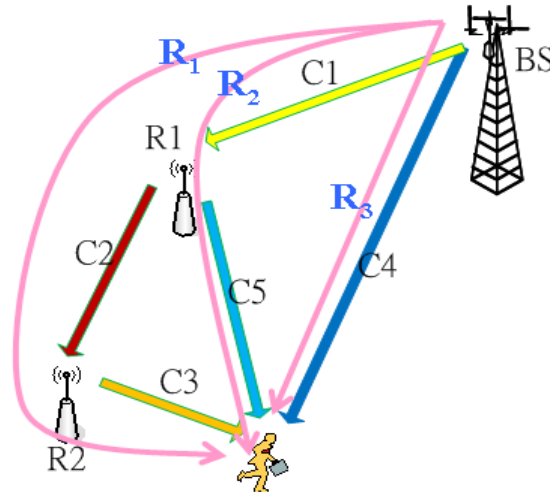


Figure 3-8 Example of Path selection

The BS needs to decide one path to user. In the platform, we should compute the packet lifetime in the scheduling, and the lifetime could express the every link channel condition (C1, C2, C3, C4, C5). The radio link R<sub>1</sub> to R<sub>p</sub>, it will dominate by the minimum channel condition: C<sub>i</sub>, when “i” is channel link index. By every radio link: R<sub>p</sub>, p is path selected, and the base station will choose the best radio link: R<sub>FP</sub> provides the user transmission information. Where R<sub>FP</sub> is final path, c is min i. The formula of path select model is shown as following:

$$R_1 = \arg \min_i (C1, C2, C3)$$

$$R_2 = \arg \min_i (C1, C5)$$

$$R_3 = \arg \min_i (C_i)$$

.....

$$R_p = \arg \min_i (C_1, C_2, \dots, C_i)$$

$$R_{FP} = \text{Max}(R_{pc}) = \text{Max}(R_{1c}, R_{2c}, R_{3c} \dots R_{pc}) \quad (3-3)$$

In our platform, the path selection was only considered two hops (Figure 3-9), so the channel conditions are only three: BS to MS, BS to RS, RS to MS.

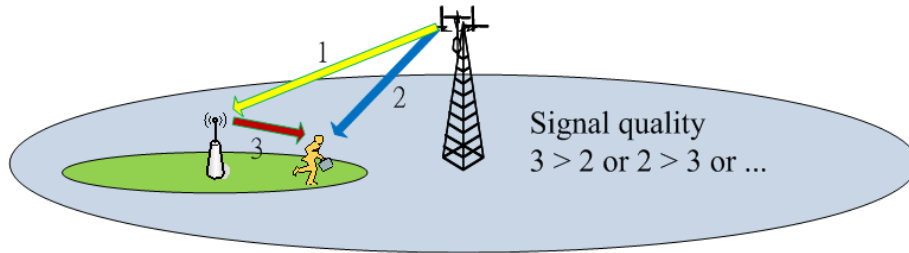


Figure 3-9 Simple Path selection

Hence, we got the three lifetimes data, and make up a simple truth table (Table 3-5). It has four link conditions, and those can separate two results: BS to MS and RS to MS. The result is come from the formula which describe above. As a result, the path was selected.

TABLE 3-5 RELATIONSHIP BETWEEN PATH-LOSS AND USAGE MODELS

Link Condition	BSMS	BSRS	RSMS	Lifetime
Condition 1	Bad	Good	Good	RSMS
Condition 2	Good	Bad	Good	BSMS
Condition 3	Good	Good	Bad	BSMS
Condition 4	Good	Bad	Bad	BSMS

In [40], the author provided a function to evaluate the path selection, it trusted the relative radio resource and sum of the product of the cost function, and use it to decide the path. In our platform, the path selection method was base on the packet lifetime planning. Hence, it could easily implement the scheme into other scheduling models.

In [41] [42], they provided a concept that is symmetric and asymmetric path selection. The symmetric scheme [41] is the user (BS or MS) used the same relay station or the same path in transmit or receive. The asymmetric scheme [42] is the downlink message direct transmit from base station to mobile station, but in the uplink the user

(MS) was used the relay station transmit to the base station. The concept might good for us in the future work.

### 3.5 Traffic model

There are three traffic models in our platform: VoIP (Voice Over Internet Protocol), FTP (File Transfer Protocol), HTTP (Hypertext transmission protocol). The traffic model implementation was followed the IEEE802.16m Evaluation Methodology Document (EMD) [9]. We consider single and mix traffic in our simulation, and the mix traffic were used the three traffics which had different ratio. About the mix traffic (Table 3-6) [9][10], we did not implement Gaming Model and Near Real Time Video Streaming Model. We transform the percentage into reasonable parts: VoIP: FTP: HTTP=30%: 10%: 20% → 50%: 16%: 34%.

TABLE 3-6 TRAFFIC MIXES

	VoIP	FTP	HTTP	NRTV	Gaming	VT	Full Buffer	Email	Mandatory Optional
VoIP only	100% * (#users = Nv*)	0%	0%	0%	0%	0%	0%	0%	Mandatory
Full Buffer Data only	0%	0%	0%	0%	0%	0%	100%, 10 users per sector	0%	Mandatory
<b>NGMN Traffic Mix</b>	<b>30%</b>	<b>10%</b>	<b>20%</b>	<b>20%</b>	<b>20%</b>	<b>0%</b>	<b>0%</b>	<b>0%</b>	<b>Optional</b>
FTP only	0%	100%	0%	0%	0%	0%	0%	0%	Optional
HTTP only	0%	0%	100%	0%	0%	0%	0%	0%	Optional
NRTV only	0%	0%	0%	100%	0%	0%	0%	0%	Optional
Gaming only	0%	0%	0%	0%	100%	0%	0%	0%	Optional
VT only	0%	0%	0%	0%	0%	100%	0%	0%	Optional
Email only	0%	0%	0%	0%	0%	0%	0%	100%	Optional
VoIP & Full Buffer Mix 1	0.5 of Nv	0%	0%	0%	0%	0%	10 users per sector	0%	Optional
VoIP & Full Buffer Mix 2	0.75 of Nv	0%	0%	0%	0%	0%	10 users per sector	0%	Optional

### 3.6 Platform architecture

To sum up the above introduction, the platform was consisted of the infrastructure, interface, radio resource management, and library (Figure 3-10). In the infrastructure, we start to the “sim.c”, which include the whole flow. The “bs.c”, “rs.c”, “ms.c” were include the function initial and function enable. The generation message was saved in the interface, the method can provide convenient data exchange like the Figure 3-10. After infrastructure and interface, the radio resource management was including the three parts: Handoff → Scheduling → Packet arrange. After the “Packet Arrange”, if the simulation time was over, we will get the simulation data.

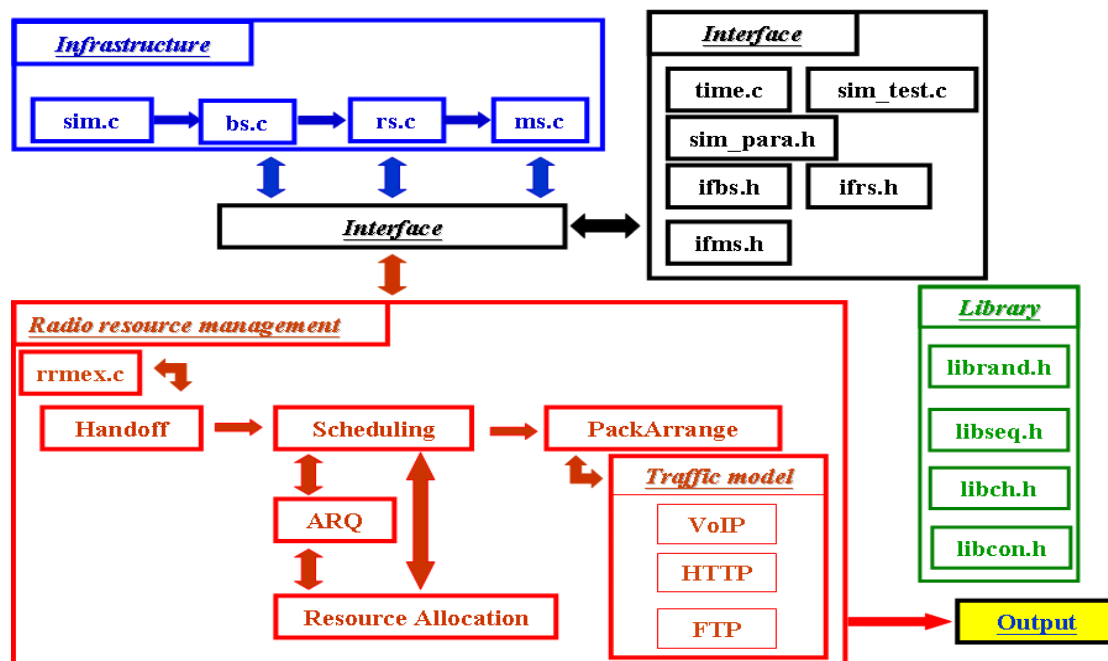


Figure 3-10 Platform architecture

Finally, table 3-7 is to summarize all the setting mentioned in this chapter for our simulation platform.

TABLE 3-7 PARAMETERS SETTING IN SIMULATION PLATFORM

Parameters	Value/Comment
Cell layout	Hexagonal grid, 19 cells (wrap around)
Sectors per cell	3
Frequency reuse factor	1x1, 1x3
Available bandwidth	10MHz in 1x1, 10/3 and 10*3 MHz in 1x3 reuse
Antenna pattern ( $\Theta_{3dB}$ , $A_m$ )	( $70^\circ$ , 20 dB), according to [33]
Beamwidth	$120^\circ$ [33]
Antenna bore-sight gain	3 dB[33]
Cell radius	1 km[32]
Transmitter/Receiver	Downlink (from BS to MSs and RSs , RS to MSs)
Duplex	TDD mode
DL/UL subframe ratio	1:1
Frame length	5ms, according to [1]
Frame structure	1024-FFT OFDMA downlink carrier allocations with PUSC, according to [1]



OFDMA symbol length	102.9 $\mu$ s, according to [34][35]
OFDMA symbols per slot	2 symbols
BS Tx power	46dBm (40 Watt), according to [32]
BS Antenna gain	17 dBi, according to [32]
BS back off	5 dB, according to [37]
RS Tx power	36dBm (4 Watt), according to [32]
RS Antenna gain	17 dBi, according to [32]
RS back off	5 dB, according to [37]
Thermal Noise Density	-173.93 dB/Hz, according to [37]
MS Noise Figure	9dB, according to [35]
MS Antenna gain	3 dBi, according to [32]
BS Antenna height	30m[32]
RS Antenna height	15m[32]
MS Antenna height	1.5m[36]
BS to RS Pathloss model	Type-D: $PL(d)=A+10\gamma\log[d/d_o]+\Delta PL_r+\Delta PL_{ht}$ for $d>d_o$ [36]
BS and RS to MS Pathloss model	Type-E: $PL(d)=38.4+35\log_{10}(d)$ dB for $50m < d < 5km$ [36]
Shadow fading model	Log-normal distribution with STD=3.4,8dB and Gudmundson's correlation model, according to [36]
Mobility model	MS speed : 30 km/hr Probability to change direction : 0.2 Max. angle for direction update : 45°
BS Power control	Max power
AMC	QPSK+CC 1/2, 16-QAM+CC 1/2, 64-QAM+CC 1/2, according to [1]
Channel assignment	Frequency first, according to [2]
Scheduling control	Early Deadline First (EDF)
Handoff	Hard handoff
Traffic model	FTP, VoIP, HTTP [9]

# CHAPTER 4

## SIMULATION RESULT

In this chapter, the performance analyses with different frequency reuse factors and with and without relay station are presented. The simulation result can be classified into two sections based on different traffic types: Real-Time-Service, and Mixed traffic. In our simulation, we assume each user served by base station and relay station is perfectly traced. It means that the serving user is enhanced with maximum boresight gain of antenna pattern. In each section, the performances of real time services and mixed traffic are demonstrated include packet drop rate, the system throughput, and AMC usage are discussed.

### 4.1 Real Time Service

In this section, the performance analysis of real-time service is presented. When users are large, the frame will be more likely fully utilized, the permutation effect will be nullifier. The interference level will be saturated when all resource units are fully used. We will only use the VoIP traffic type in following simulation.

#### 4.1.1 AMC usage and throughput for different cell radius

First we check the influence of the distance on system performance. In [32], the cell radius was 1000m, and the simulation result was show that we had the higher BPSK ratio in figure 4-1. Hence, we try to simulate the cell radius 800m as compared with 1000m. In figure 4-2, we will find whether we'll get the better AMC percentage if we decrease the cell radius. The most of transmissions are under QPSK and 16QAM modulation, and with the increase of traffic loading, the utilization of QPSK burst profile is getting higher. About the receive signal, here have a formula:

$$\text{Receive power} = \text{Transmit power} * \text{constant} / (\text{radius})^\alpha \quad (4-1)$$

$\alpha = 2 \sim 4$ , 2 mean in free space, 4 means in urban environment

Follow the formula, the system interference will increase by decrease the distance, but the user also can get the higher transmit power. The system SINR will be better. Hence we can find the interference level is increase with traffic loading and increasing the cell radius. In figure 4-3 and figure 4-4 is show the system throughput and packet drop rate at the cell radius 800m and 1000m. It can clear display of the simulation result that is 800m will have the batter throughput and lower packet drop

rate. Although the 800m had the better performance, we will continue using 1000m in our whole simulation, because we consider the continuity between the parts of our research.

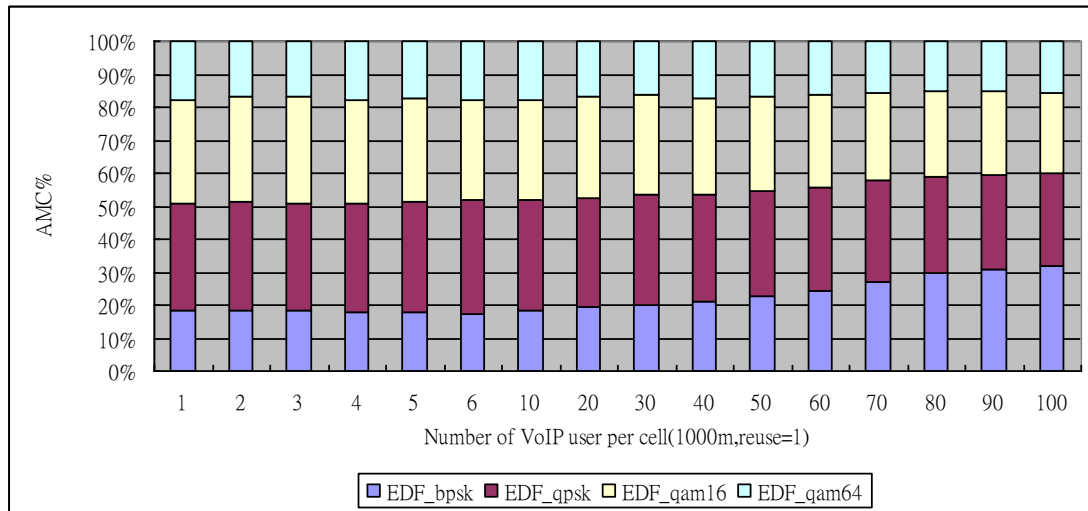


Figure 4-1 AMC usage of VoIP type at cell radius 1000m

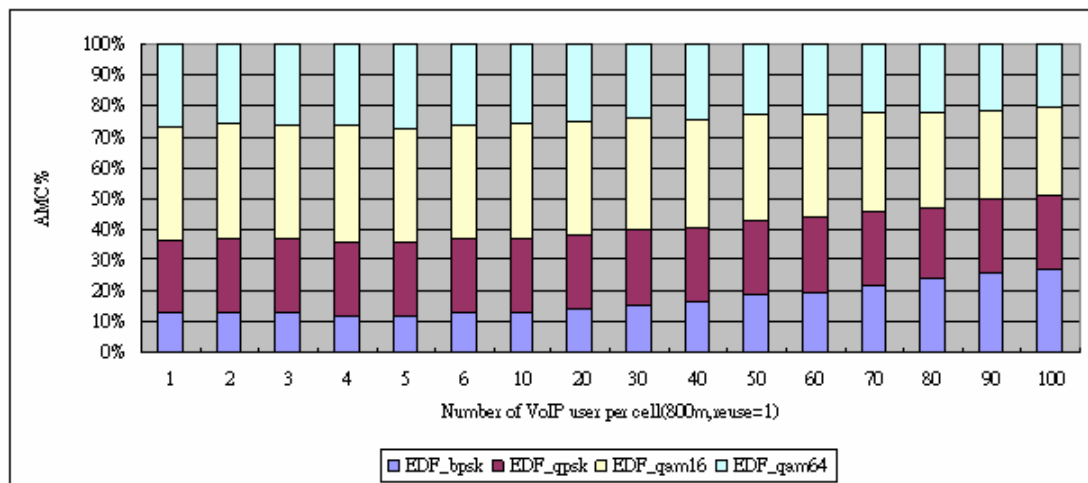


Figure 4-2 AMC usage of VoIP type at cell radius 800m

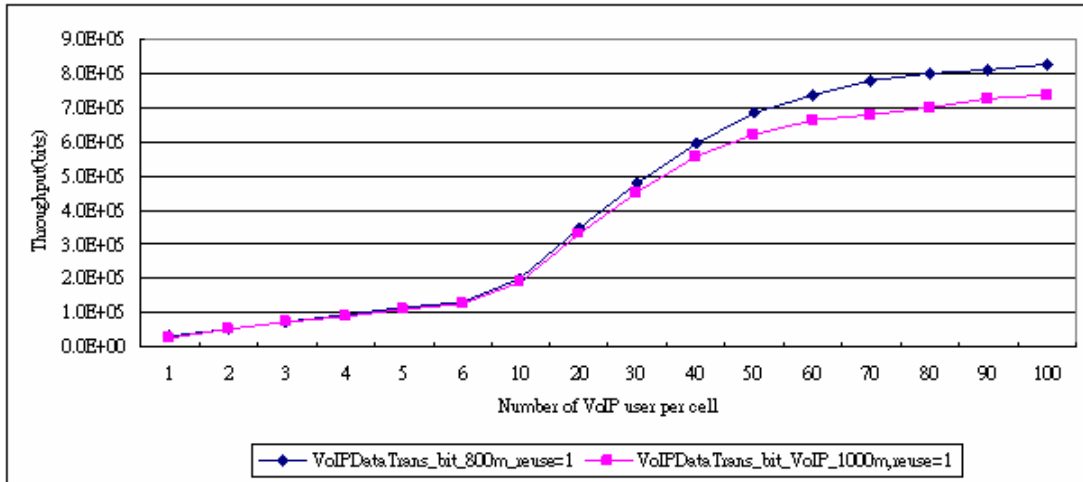


Figure 4-3 Throughput at cell radius 800m and 1000m

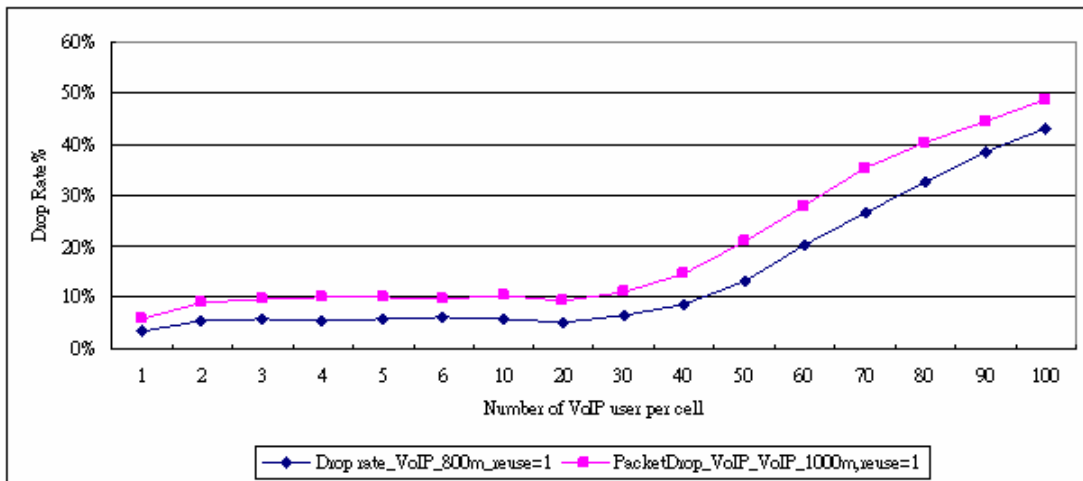


Figure 4-4 Packet drop rate at cell radius 800m and 1000m

### 4.1.2 AMC usage and throughput for different frequency reuse

At this section, we will check the influence of the frequency reuse factor. The cell's frequency reuse factor in our simulation platform has two select, 1 and 3. The total bandwidth of frequency reuse factor 1 is 10MHz in our simulation. Frequency reuse factor 3 needs used triple bandwidth, which is 30MHz. Another condition is reuse factor 3 the system have trisect bandwidth that is 10MHz. The cell with frequency reuse factor 3 has longer distance between two cells used the same bandwidth than frequency reuse factor 1. Therefore, the interference in frequency reuse factor 3 is lower due to stronger interference path loss caused by longer distance. In the simulation result (Figure 4-1 versus Figure 4-5, Figure 4-2 versus Figure 4-6), we can see that the frequency reuse factor 3 can provide better transmission environment.

In Figure 4-7, Figure 4-8, we try to present the performance that is in the different distance and different frequency reuse factor. It is very clear that is the short radius and frequency reuse factor equal to 3 can let the throughput maximum and drop rate minimum. And the frequency reuse factor 1 has more interference then frequency reuse factor 3 no matter the distance.

In Figure 4-9, Figure 4-10, we try to find the influence in different system bandwidth. As above, when the frequency reuse factor equal to 3, the system bandwidth we can provide 30MHz and 10MHz in three cells. About the relationship, here have a formula:

$$C=W * \log_2(1+S / N) \quad (4-2)$$

C: Channel Capacity, bits/s; W: Bandwidth, Hz; S: signal power; N: noise power

It is very clear that the system bandwidth will influence the system capacity. The simulation results were show that the frequency reuse factor equal to three and the cell bandwidth equal to 30MHz (three cells) will get the best performance. But we consider the realism that will use the frequency reuse factor 1 in our further experiment.

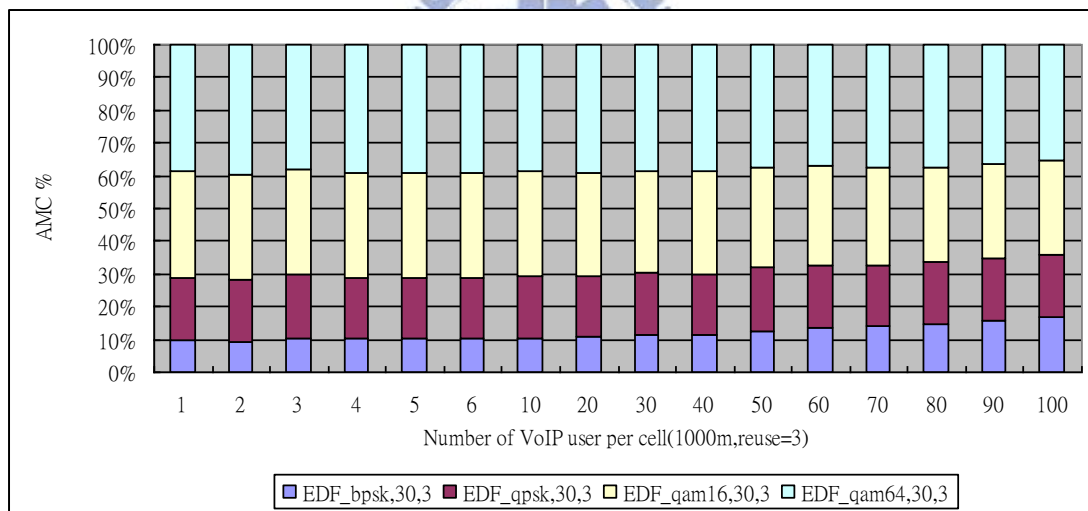


Figure 4-5 AMC usage of VoIP type at frequency reuse factor = 3(1000m)

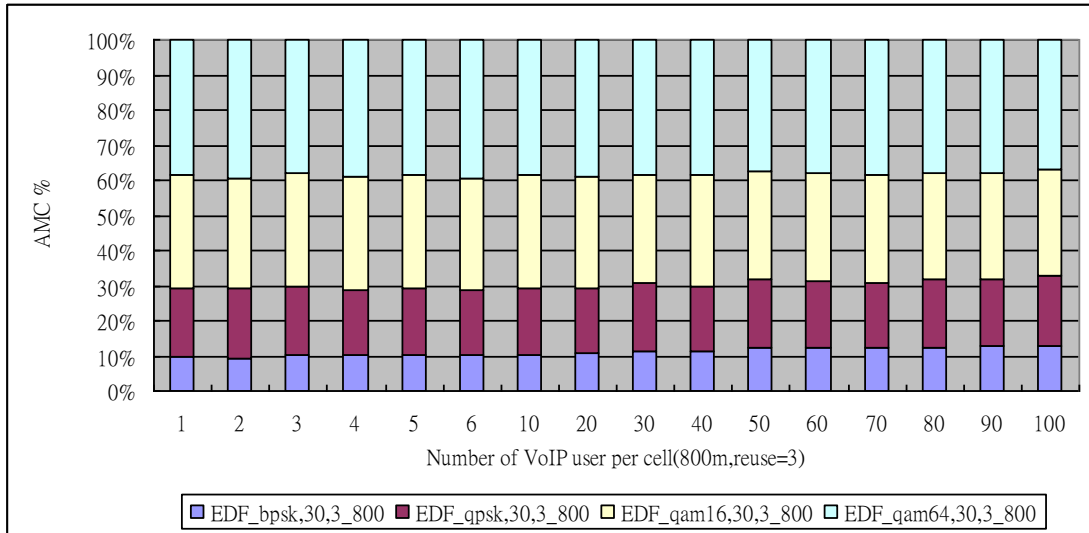


Figure 4-6 AMC usage of VoIP type at frequency reuse factor = 3(800m)

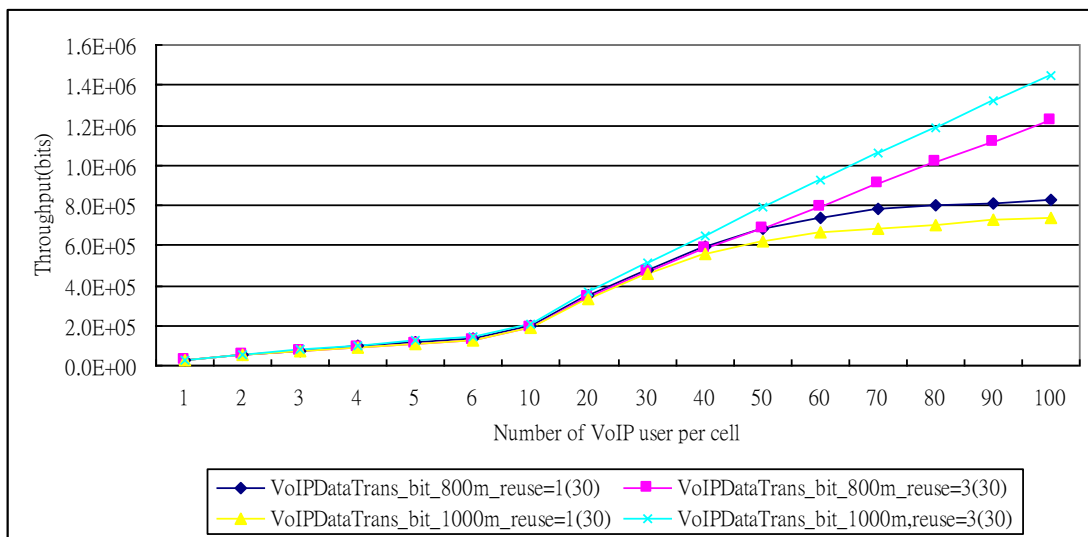


Figure 4-7 Throughputs at frequency reuse factor 1 and 3(800m & 1000m)

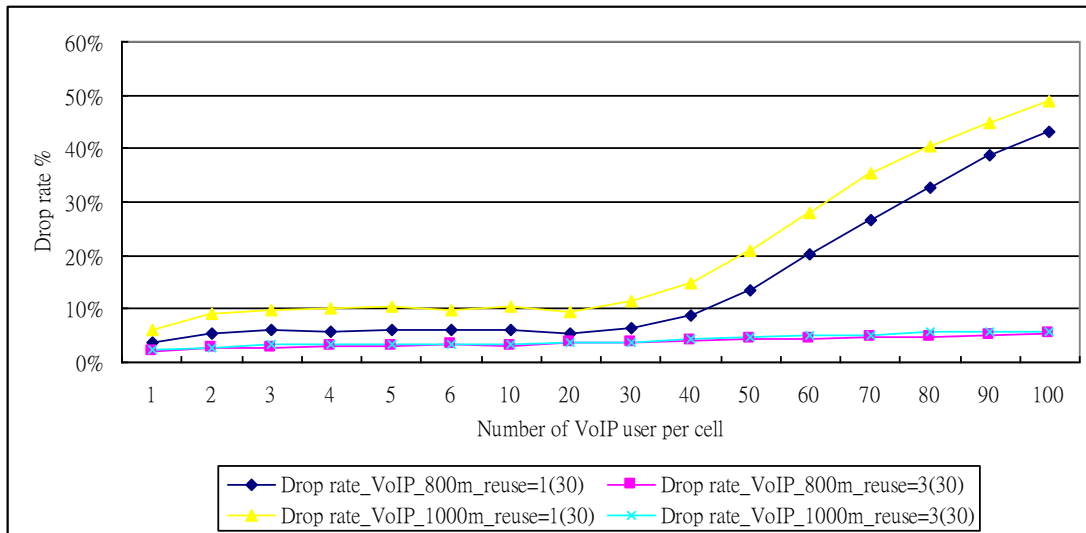


Figure 4-8 Packet drop rate at frequency reuse factor 1 and 3(800m & 1000m)

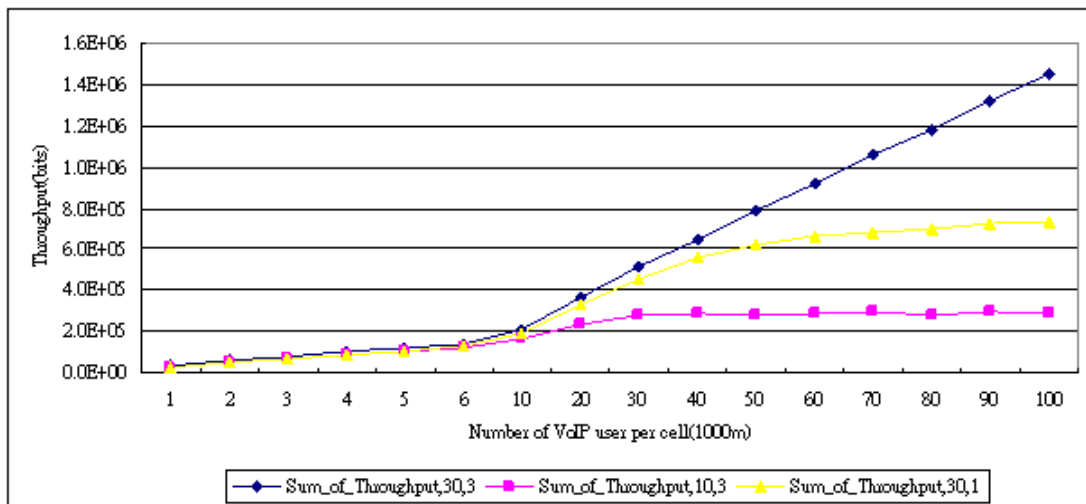


Figure 4-9 Throughputs at frequency reuse factor 1 and 3(1000m)

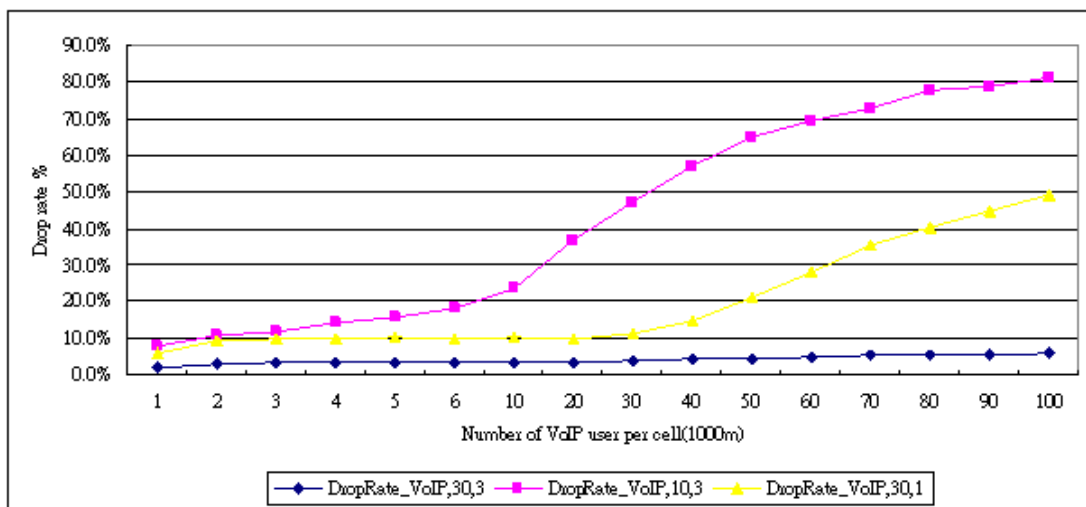


Figure 4-10 Packet drop rate at frequency reuse factor 1 and 3(1000m)

### 4.1.3 AMC usage and throughput for different system

At this section, we try to find out the difference in the two systems: 802.16e and 802.16j. In this simulation we use some skill let the platform can switch between the two systems, the skill like the resource allocation, scheduling, etc. In the simulation environment, the two results (Figure 4-11, Figure 4-12) were very similar below 30 users, but over 30 the interference were become poor in the 802.16j transmit environment. The relation result we can see in Figure 4-13 and Figure 4-14. In Figure 4-12, the BPSK user percentage increase cause of the interference between the BS and RSs. This reason is that as user number increases, more users may be served by a BS and raise interference to the link between RS and BS. In the hexagon cell, the base station will serve partial MS user and relay station. The base station transmits information to the MS and RS in the same access zone, these will cause some interference. When the system have few users, they have low probability fall in the high interference area, when the users were increase, they will have high probability fall in the high interference area. Then in base station point of view, 802.16e the system have the constant AMC percentage, but in 802.16j have become poor AMC percentage when user is increased. But below 40 users, the advantage of using relay station will be found.

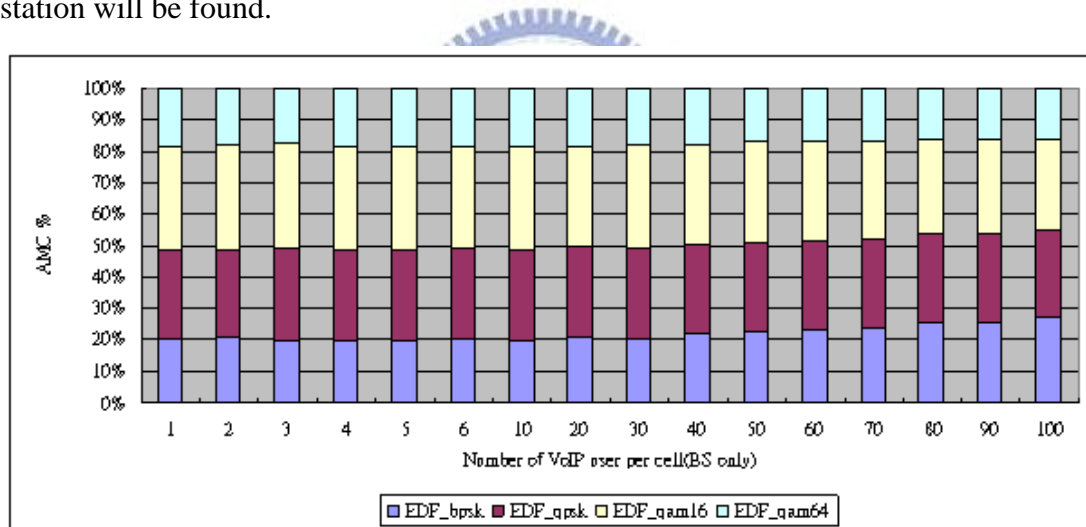


Figure 4-11 AMC usage of VoIP type at 802.16e



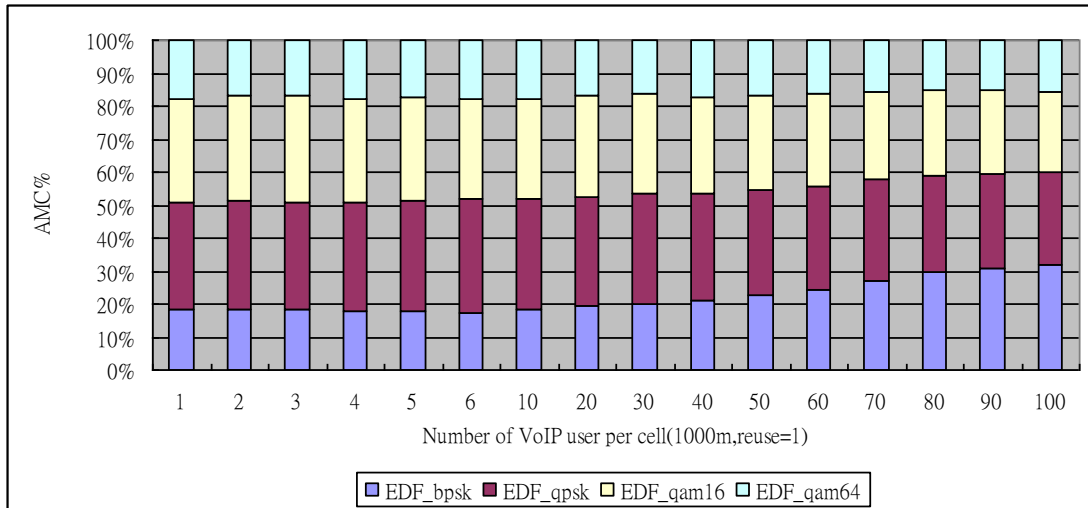


Figure 4-12 AMC usage of VoIP type at 802.16j

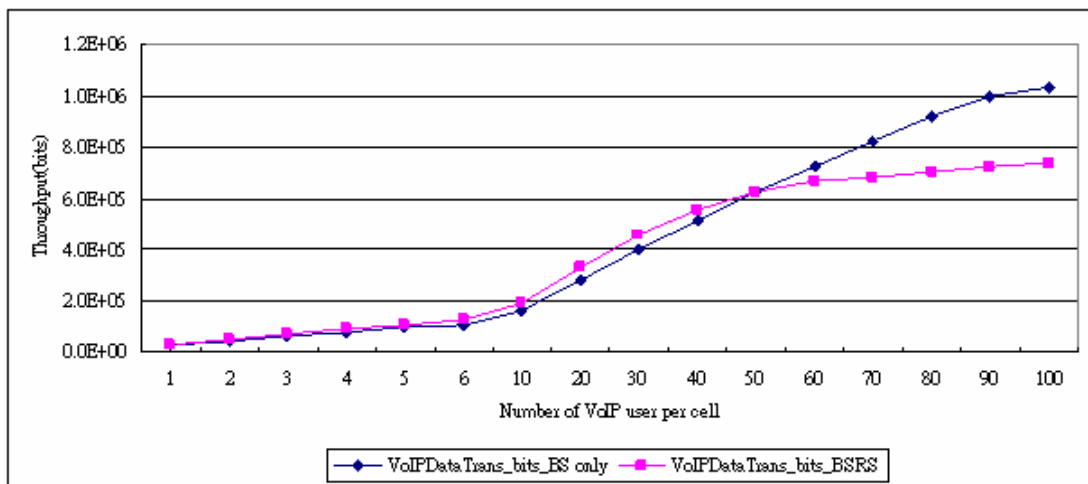


Figure 4-13 Throughputs at 802.16e and 802.16j

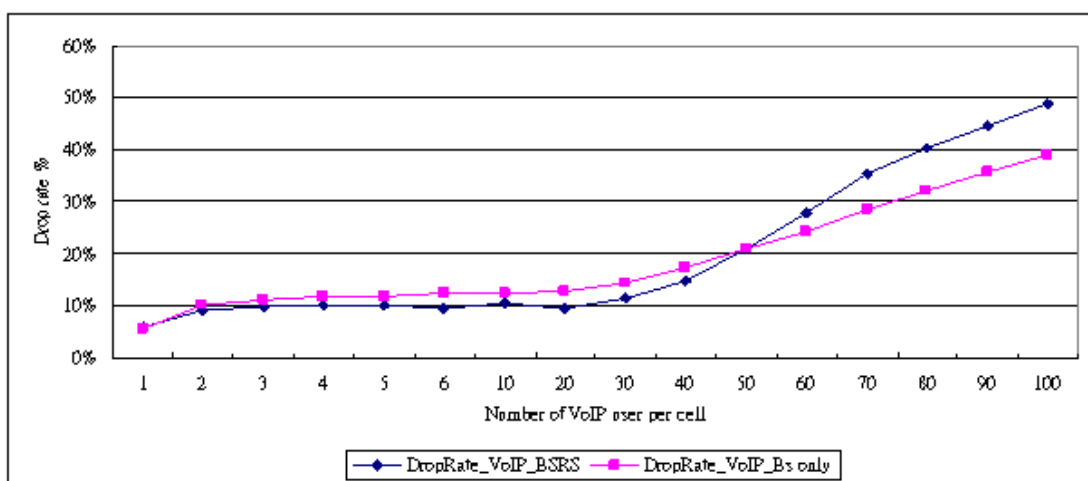


Figure 4-14 Packet drop rate at 802.16e and 802.16j

## 4.2 Mix traffic Service

In this section, the performance analysis of mix traffic service is presented. We will use the three traffic types (VoIP=50%, FTP=16%, HTTP=34%) in following simulation. And we will find out the relation in different system and different relay station number.

### 4.2.1 AMC usage and throughput for different system

At this section, we will check again the difference in the two systems: 802.16e and 802.16j. At this time we use the mix traffic type to evaluate the system performance. In Figure 4-15, Figure 4-16, the two systems have the same AMC percentage ratio when user number are below 30, and when user number are over 30, it also got the same curve like the Figure 4-12. But the different in the two services is in the mix traffic service the FTP service will be preempted by VoIP services; therefore the FTP throughput will be decrease with increasing number of VoIP users. In Figure 4-17, Figure 4-18, we can get the two results. First, the simulation result show that the non-real-time service throughput will decrease as the number of real-time service increase. It is reasonable because transmission of real time service will take the resource of transmission opportunity from non real time service. Second, the 802.16j system throughput will always less then 802.16e. In our simulation platform, the total downlink resource is 12 OFDMA slots. The 16j base station was only controlled 7 OFDMA slots and another 5 OFDMA slots was controlled by the relay station. According to the second result, if the resource in relay zone will not fully utilize, it will be a waste. Another limiting factor is coding rate, in our simulation platform we only use 1/2 coding rate, but in standard [1] it prepare three kinds of coding rate: 1/2, 2/3, 3/4. If we have high SINR in the link, it will waste the performance of relay station.

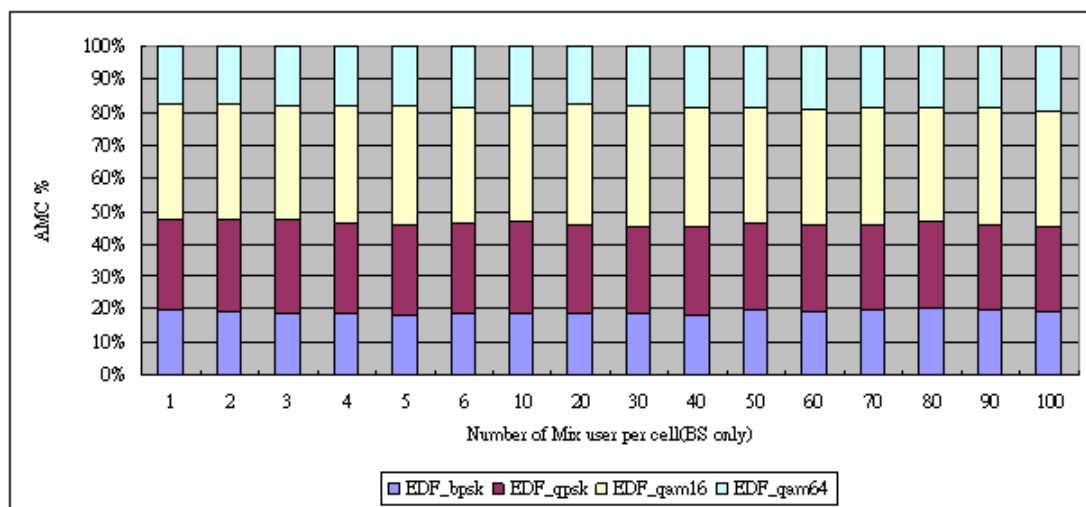


Figure 4-15 AMC usage of mix traffic at 802.16e

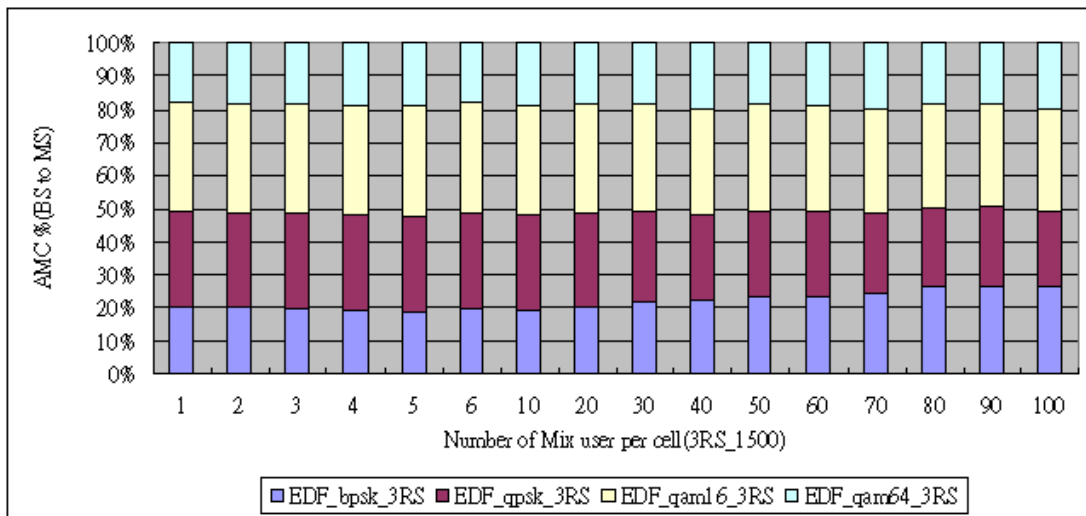


Figure 4-16 AMC usage of mix traffic at 802.16j

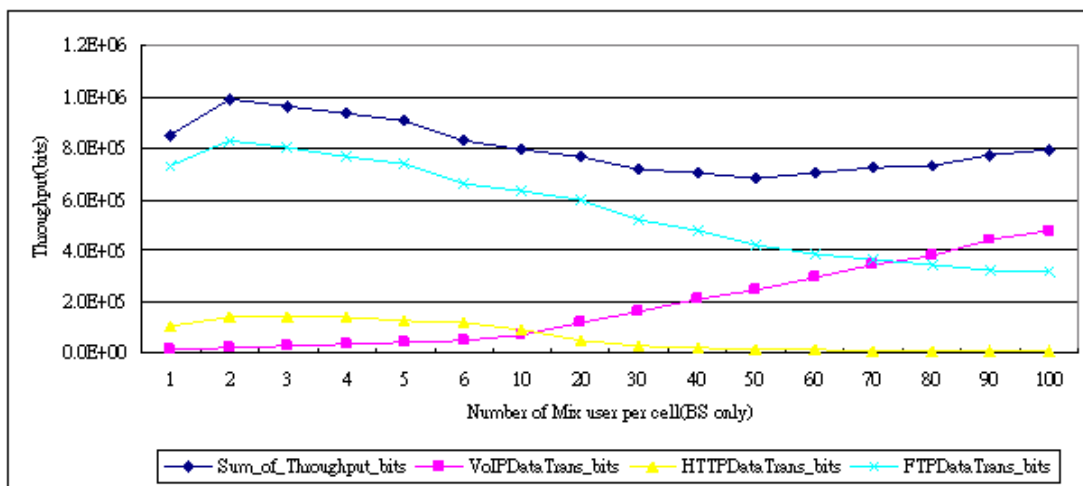


Figure 4-17 Throughputs of mix traffic at 802.16e

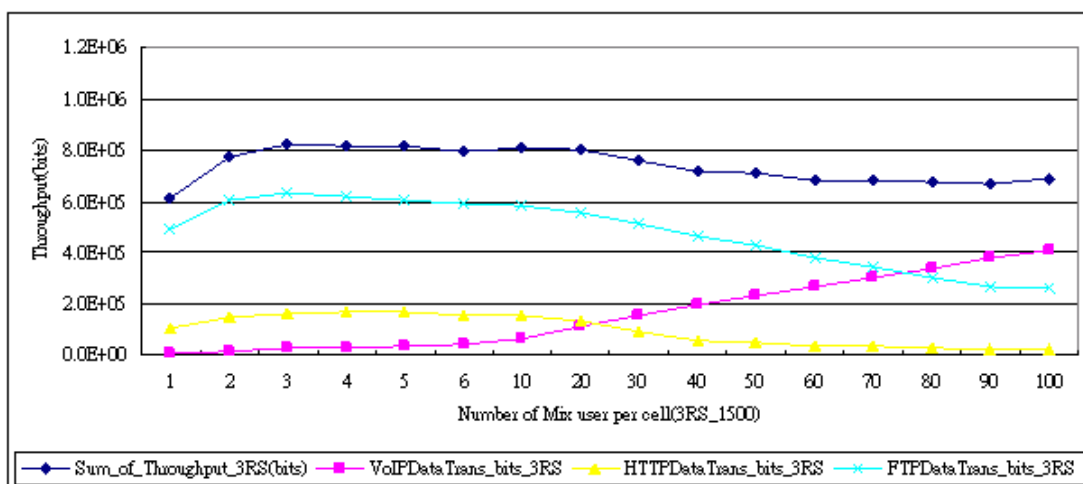


Figure 4-18 Throughputs of mix traffic at 802.16j

## 4.2.2 AMC usage and throughput for different relay station number

At this section, we will check the relation between the relay station number and the system performance. In Figure 4-19, Figure 4-20, Figure 4-21 were show the three different number of relay station (the relay station number is 3, 6, 9) for system throughput. In Figure 4-22 (Total throughput), Figure 4-23 (HTTP throughput), Figure 4-24 (FTP throughput), Figure 4-25 (VoIP throughput) were show the individual result at the number of 3, 6 and 9 relay stations. In Figure 4-26, the VoIP packet drop rate of mix traffic at the 3, 6 and 9 relay stations.

We will find when the relay station numbers were increase, the system throughput will decrease. Here have two reasons, first is the effective bandwidth was decrease, it reduce the effective resource unit per relay station. The formula is:

$$\text{Effective bandwidth} = \text{System bandwidth (10MHz)} / \text{Relay station number} \quad (4-3)$$

The second is the base station did not prepare the relation directional antenna to every relay station, so the transmission efficiency will not good, although the link between BS and RS is LOS.

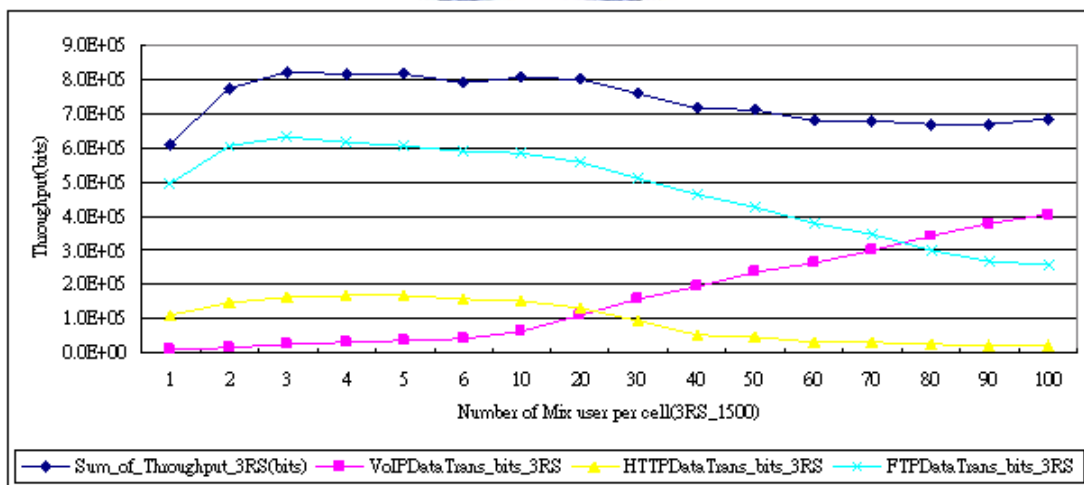


Figure 4-19 Throughputs of mix traffic at 3 relay stations

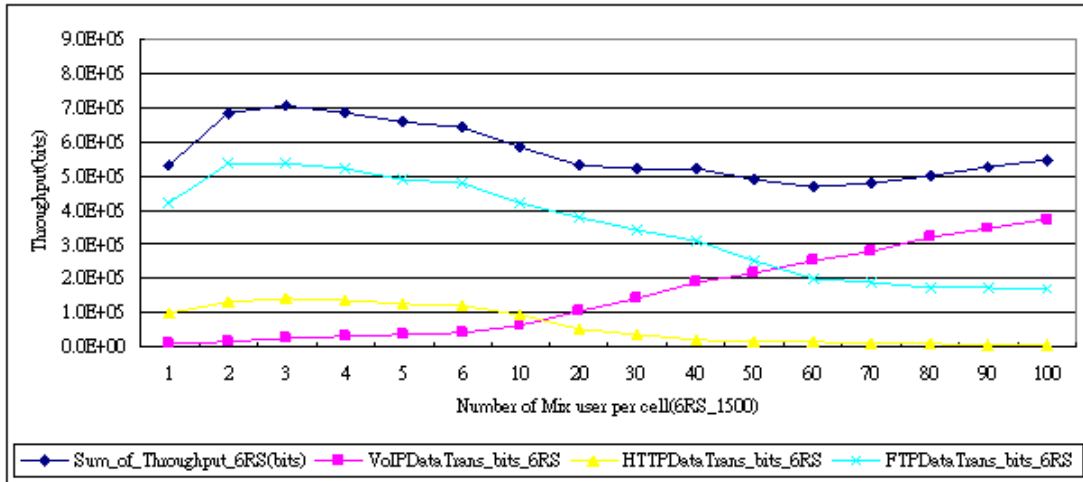


Figure 4-20 Throughputs of mix traffic at 6 relay stations

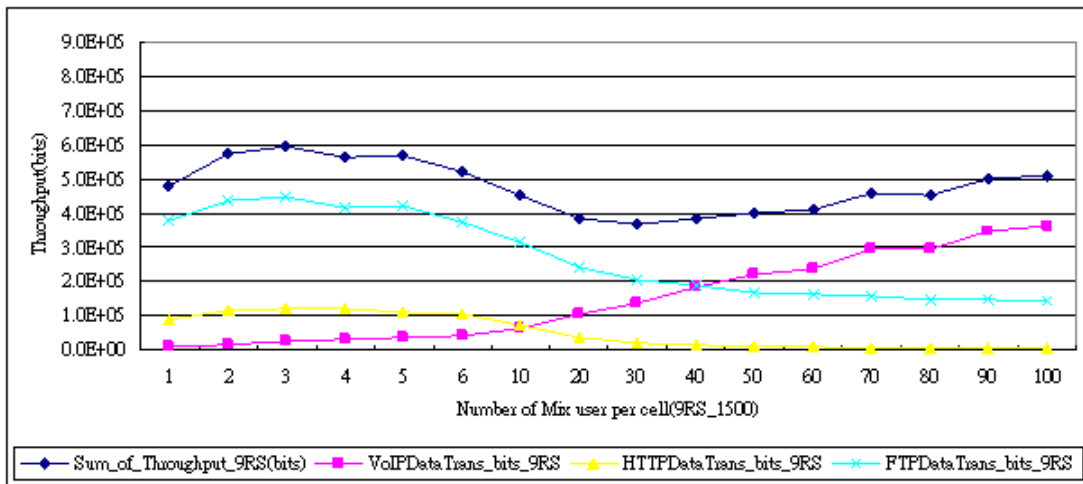


Figure 4-21 Throughputs of mix traffic at 9 relay stations

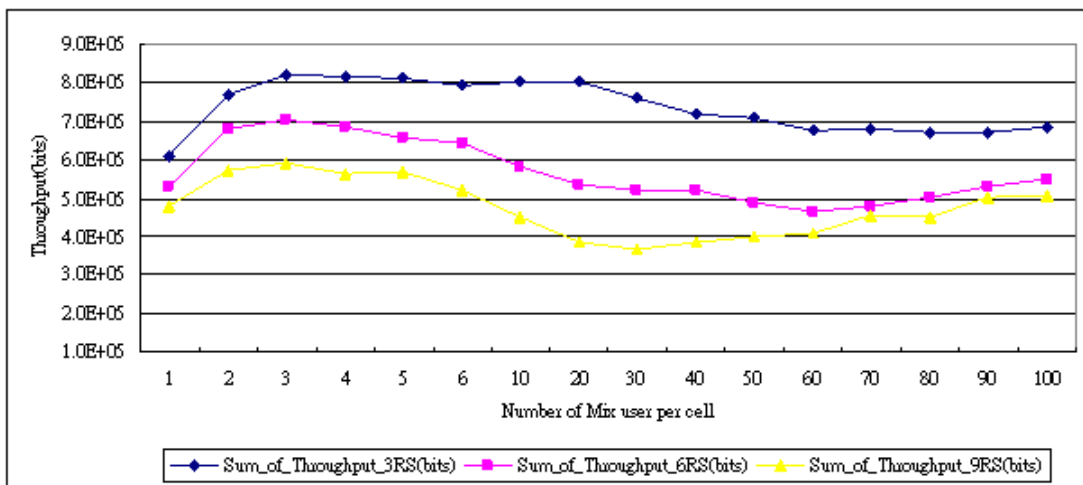


Figure 4-22 System throughputs of mix traffic at 3, 6 and 9 relay stations

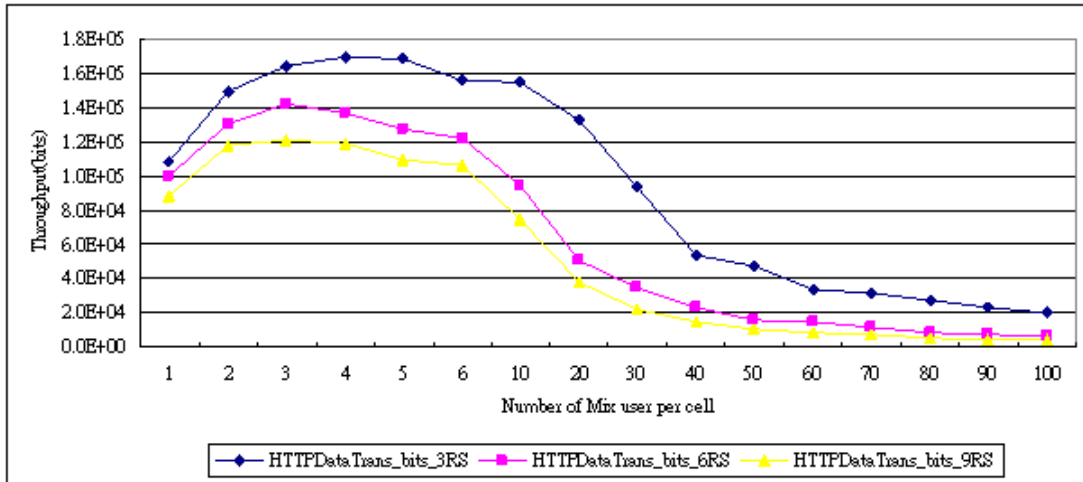


Figure 4-23 HTTP throughputs of mix traffic at 3, 6 and 9 relay stations

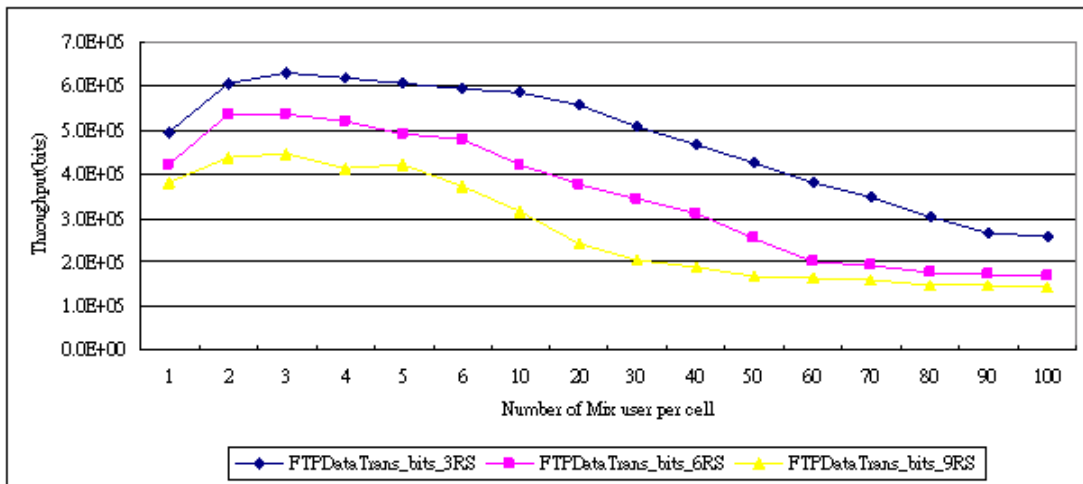


Figure 4-24 FTP throughputs of mix traffic at 3, 6 and 9 relay stations

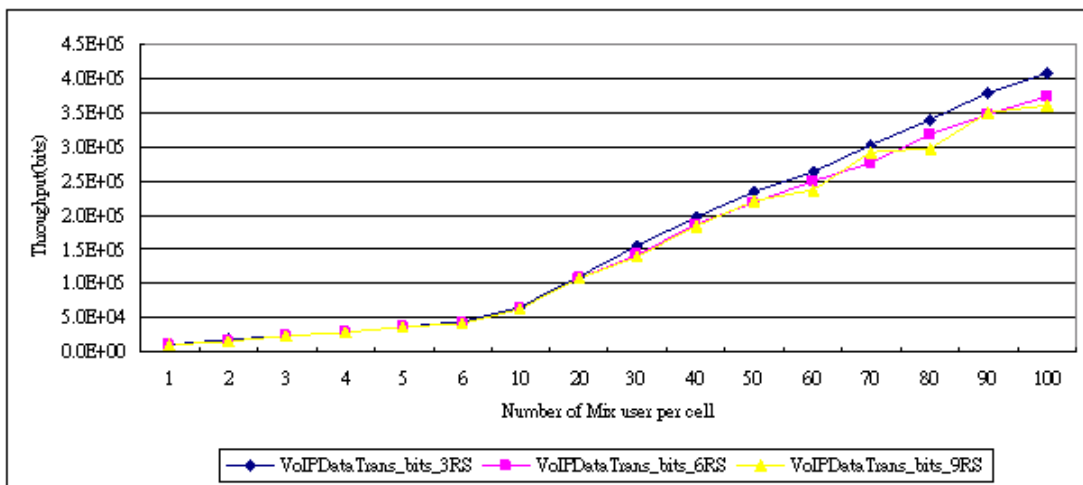


Figure 4-25 VoIP throughputs of mix traffic at 3, 6 and 9 relay stations

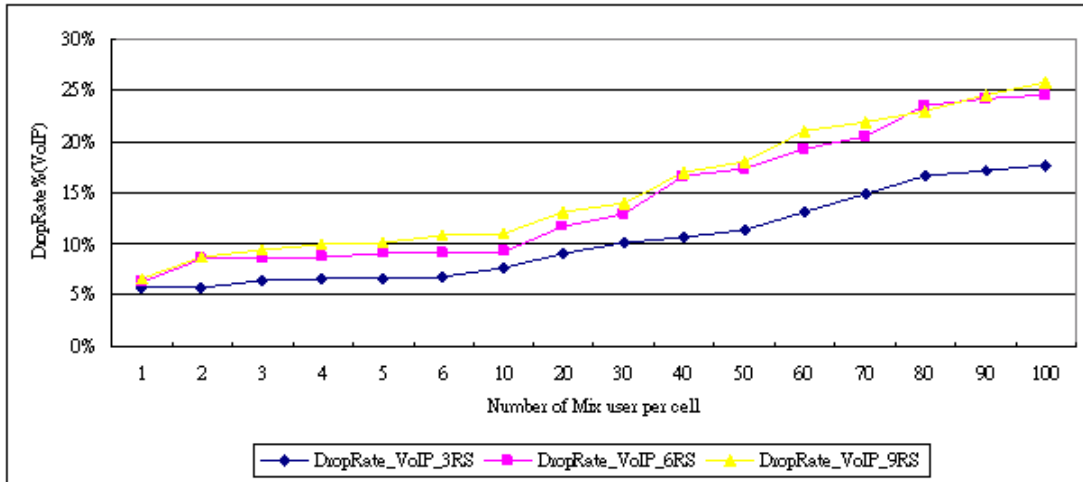


Figure 4-26 VoIP Packet drop rate of mix traffic at 3, 6 and 9 relay stations

In the simulation result, the amount of relay station numbers will not be affects the link quality between BS to MS and BS to RS. Therefore, we only show Figure 4-27 (3 relay stations) represented the base station to the whole system, Figure 4-28 (9 relay stations) represented the link between the base station to the relay stations. It can be seen that burst profile BPSK is barely appear. That is because the interference is not serious in BS to RS.

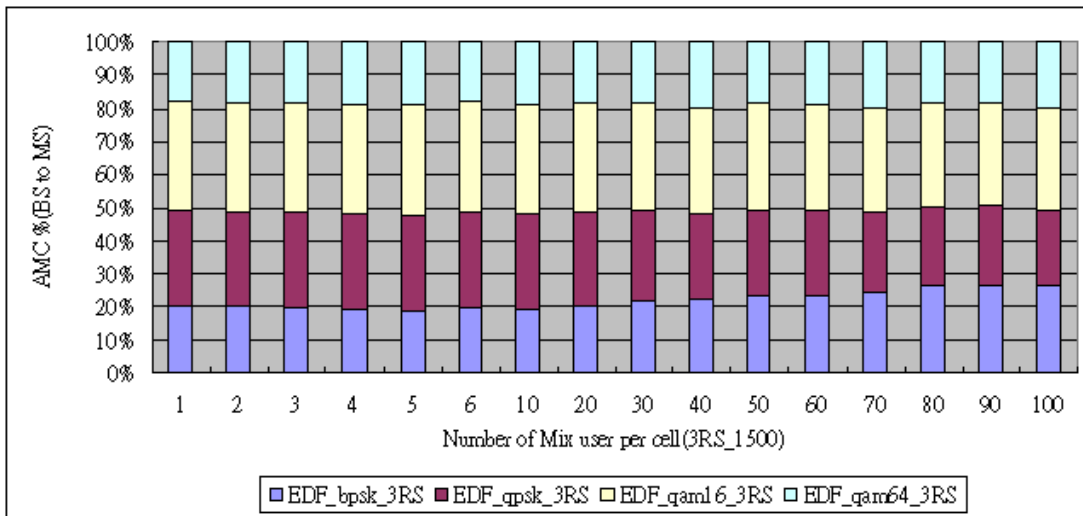


Figure 4-27 Base station AMC usage of mix traffic at 3 relay stations

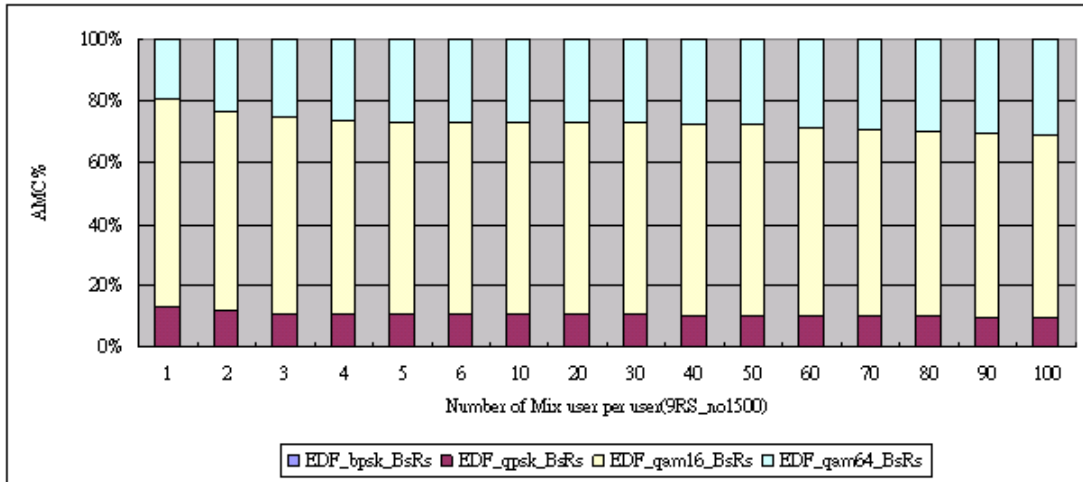


Figure 4-28 Base station to relay station AMC usage of mix traffic at 9 relay stations





## CHAPTER 5

### CONCLUSION AND FUTURE WORK

In this thesis, our contributions are (1) The Mobile Multihop Relay(MMR) system level platform establishment for supporting MAC layer with basic resource management in IEEE 802.16j draft standard and (2) The performance study of IEEE 802.16j system.

This platform is used for preliminary understanding of IEEE 802.16j system. In this simulator, we focus on studying the overall and complete downlink performance and investigating the advantages and disadvantages of different environment factor like the distance, frequency reuse factor and the number of relay station. The applied scheduling algorithm is the Early Deadline First (EDF). Secondly, real time service and mix traffic service performance is studied. After that, real time service performance with regarding to different environment factor is investigated. From these performance simulations, the conclusions are described as below: For real time service, the distance and frequency reuse factor will influence the throughput and packet drop rate. The shorter cell radius can provide better transmit environment. The frequency reuse factor will decide the interference level and the effective bandwidth. The relay station number will also effect the effective transmit bandwidth and interference level. After simulating, we find the transparent relay station may not be the perfect. Transparent relay station means it can do the throughput enhancement. We think the actuality meaning which helps the worst case user to improve the service quality like the BPSK user upgrade to the QPSK or other AMC, but everything is not ideal. The transparent relay station will have something done at the expense. The effective resource units were consumption on the resource segment. This will let the total system throughput degrade.

Hence, in future work, we need to let the more smart mechanism in transparent relay station. We need let the base station can partial control the relay zone, if the relay zone will not fully utilize. We did not setup enough corresponding coding rate, so in the future we need to set up whole coding rate to make up more diversified in our platform. We need to setup the relation directional antenna technical to provide every relay station have the better radio frequency (RF) condition, like the beamforming. With beamforming, the co-channel interference is reduced and SINR is enhanced so that the transmission quality will be promoted. Besides, the relay station setup in the cell edge will improve the poor RF, but this situation needs to consider the interference in the neighbor cell. In the future, the research in the non- transparent

relay station will have more benefit. However, it is more complicated than transparent relay station. The trade-off shall be taken into consideration.



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