國立交通大學

電子工程學系電子研究所碩士班

碩 士 論 文

WIMAX 系統下的擬真系統設計

Emulation System design with WIMAX SYSTEM

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摘　要

多媒體應用的重要性日趨成長。而即時性傳輸也將成為次世代行動通訊應用的主軸。在媒體傳輸控制層封包排程演算法設計的優劣勢必會影響到系統的效能。因此演算法的分析與驗證是相當重要的。先前在 MAC 層機制驗證所使用的方法上，我們通常是透過編寫程式碼的方法來實現。我們透過在程式上預存封包，接著將之做切割，由另一函式來做收取與重組。這些工作在相同電腦的相同程式中完成。我們經由電腦程式創造傳輸的環境，但是我們並未透過真實的環境進行傳輸。透過數據資料我們也未必有辦法了解整個程式運作情形的好壞。

本論文中，我們提供了一種新的方法來解決這樣的問題。我們開發了一個稱為”MAC 擬真系統”的實驗平台，或 MAC 模擬器，來作為 MAC 層的驗證系統。而我們透過此一系統，亦可將整個傳輸的過程以及具象化，讓使用者更容易了解到整個流程。

An Emulation System design with WIMAX SYSTEM

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ABSTRACT

The application of multimedia is more and more important today. Real time service will be the main scheme in the next generation mobile communication. The scheduling algorithm of the SDU will indeed affect the system performance a lot. So it is an important issue to verify if a scheduling algorithm works well with a system. But in previous work, verification of MAC mechanism is usually done in “artificial situation”. Data and video streaming are stored in the program, and then it is fragmented and then combined in that program. Environmental situations are also generated by program. Actually we don`t really transmit it. Everything may looks well but we still have no idea actually know it works.

A new approach is proposed in this thesis to solve this problem. We design a platform called “MAC Emulation System” or simply “MAC Emulator” to do system verification. We can also visualize the whole picture by transmitting via physical medium. So the user of the platform may obtain better understanding.

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又走到學期的尾聲。不過這學期不同的是，曲曲折折中，很高興總算要畢業了。我想最該要最感謝的就是黃經堯老師，雖然我一路中出了不少差錯，但是感謝黃老師一直不厭其煩的教導，沒有您，我就沒有一再重新的機會。我想很誠心的感謝黃經堯老師的包容，對您，除了謝謝還是謝謝。

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CHAPTER 1

INTRODUCTION

1.1 Research Approach

The wireless communication technology is more and more important today. Among many systems, the Worldwide Interoperability for Microwave Access (WIMAX) [1] is most popular of them. It is designed by the IEEE 802.16 group [2] and can support high data rate transmission up to 54Mbps. And it could support heterogeneous network [3] for high speed transmission service. So it is very suitable for the next generation 4G system that supports multimedia services at vehicular speed.

However, the efficiency of the scheduling algorithm and other features will affect the performance of the system. So it is very important to verify the performance of the system and to test the modulus we design.

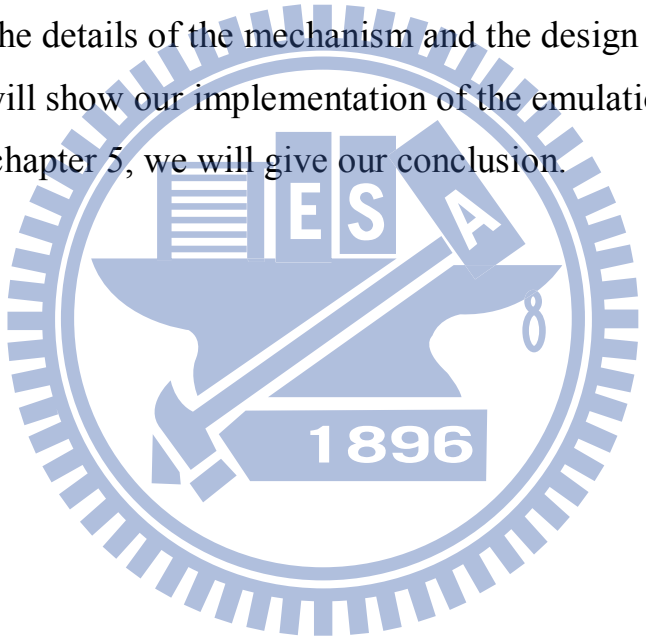
In previous work, system verification is often done on simulation tools, such as the Matlab [4] [5] [6]. The defect is that we can get nothing more than numeric data. Although we may know how fast the system runs, or know parameters such as the frame rate or the throughput, sometimes we are still not able to image them. Besides, we usually skip the data plane. That means we don`t really transmit these data, we only simulate the behavior. The defects is that we don`t actually know how this performs under real environment.

To solve the problem, we propose a new verification methodology. In this thesis, we design an architecture called MAC emulation system or simply, MAC emulator. We will also realize the design for WIMAX

medium access control (MAC) layer. Although we choose to design the WIMAX system, this concept can be generalized to all other systems as well.

1.2 Thesis Outline

The rest of this thesis is organized as follows: in Chapter 2, we will introduce the WIMAX system. We will mainly focus on the MAC layer. But some important features of the physical layer (PHY) will be introduced as well. In chapter 3, we will introduce the concept of the emulation system, and propose our designed architecture flow chart. We will introduce the details of the mechanism and the design concept. In chapter 4, we will show our implementation of the emulation system. And finally in chapter 5, we will give our conclusion.



CHAPTER 2

AN INTRODUCTION TO THE WIMAX SYSTEMS

In this chapter, we give a quick overview of the 802.16e, or the WIMAX system, and also the MAC layer and PHY layer but focus on the MAC layer. The WIMAX system provides high speed transmission in mobile systems. It provides two operation modes: Point to Multi-Point (PMP) and Mesh. In PMP mode, the network is composed of a base station (BS) and many subscriber stations (SSs). The BS works as a central controller that coordinates many SSs. In Mesh mode, all nodes are equal and hence there is no central controller. All serves are peer-to-peer. And the whole system works as a distributed network. In this thesis, we choose the PMP mode.

2.1 Fundamentals Of The 802.16e

In December 2005, the IEEE association proposed 802.16e-2005, which is a broadband wireless access system. It is an enhanced version of 802.16e-2004, and also called mobile WIMAX. It could supports the subscriber stations moving at very high speed.

Because of its high speed supporting feature, the WIMAX system can fill the gap between the high data rate WLAN system and the high mobility cellular systems.

Because the WIMAX system has the feature above, it could be applied to real-time services and also the broadband network services, such as VoIP, HTTP or multimedia service. For different services, we need to provide different mechanism to meet different quality of service (Qos) constrain.

2.2 An Introduction To The 802.16e MAC

2.2.1 MAC Layer Description And Data Flow

In WIMAX systems, the purpose of MAC layer is to deal with the problem of resource management. The main data unit from upper layer is called service data unit (SDU). After packing or fragmenting process, SDUs will be changed into PDUs, which will be later passed to the physical layer (PHY). When SDUs come from upper layer, MAC will fragment or pack them into appropriate size. If the size of the SDU is too large, it will be fragmented into smaller size. If the channel condition is good, some small SDUs will also be packed. Then they will be contained in the payload of the MAC Protocol Data Unit (MPDU). Then it will be transmitted into Physical Layer (PHY).

The fragmentation and packing mechanism will be introduced later in this chapter. The dataflow from the upper layer to MAC and from MAC to PHY is showed in figure 2-1, which demonstrates the concept of data flow between layers. In transmitter terminal, each layer receives SDU and transmits PDU to the next layer, both for the MAC layer and the PHY layer. The receiver terminal does the reversed action.

2.2.2 MAC Data Formats

The MAC Protocol Data Unit (MPDU) is the unit of data exchange between MAC BS and MS. A MPDU could be generated from multiple SDUs (through packing) or be generated from only part of an SDU.

A MPDU begins with a fixed-length generic MAC header, and it may be followed by an optional variable length payload and an optional 32bits Cyclic Redundancy Check (CRC) field. The structure of MPDU showed in figure 2-2.

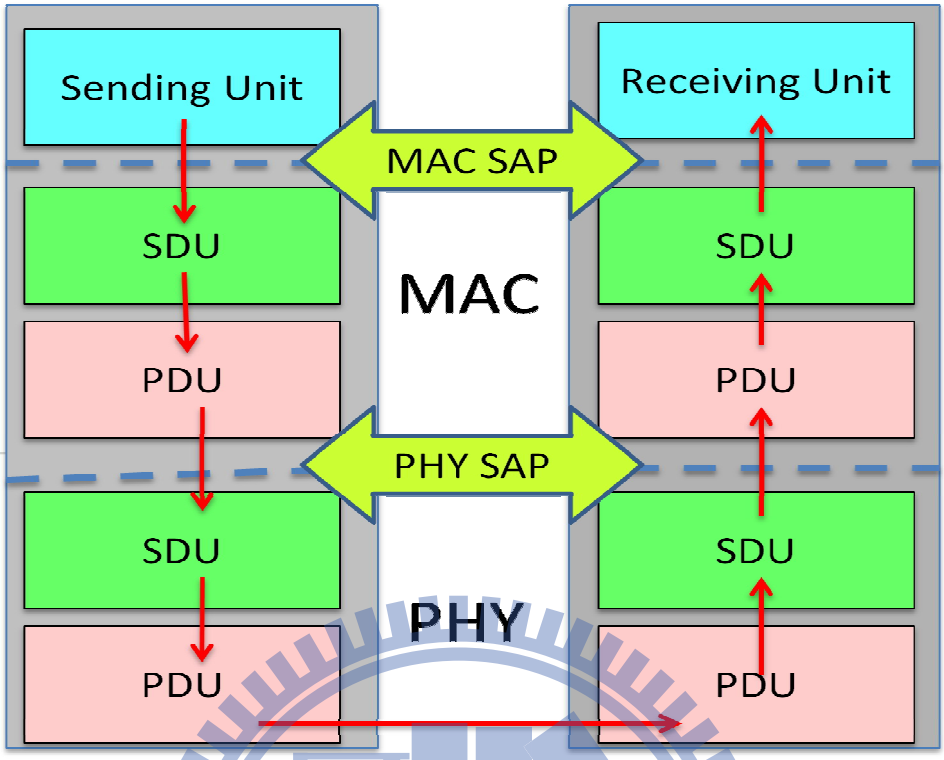


Figure 2-1 Dataflow of MAC and PHY

Figure 2-2 Format of MPDU

Some MPDU may also include sub-headers in the payload field, especially when it is a fragmented or packed PDU. This way these SDUs could be recovered. Also some PDUs may only have header, for example, the MAC signaling headers. Such as bandwidth request, uplink transmit power report, CINR report, CQICH allocation request, PHY channel report, uplink sleep control, SN report, and feedback functionalities. They don`t have the payload and the CRC field.

2.2.3 MPDU Fragmentation And Packing

In the WIMAX system, when SDUs come from the upper layer, it should be processed to meet some constrains. First of all, the maximum size of the MPDU cannot exceed 2048 bytes. The fragmentation mechanism could help this. SDUs that are too large will be divided into smaller pieces, and be included in different MPDU payloads. The picture of the fragmentation is showed in figure 2-3. Besides, it could also decrease the probability of error occurrence. If the size of the MPDU is too large, transmission errors will be produced more easily.

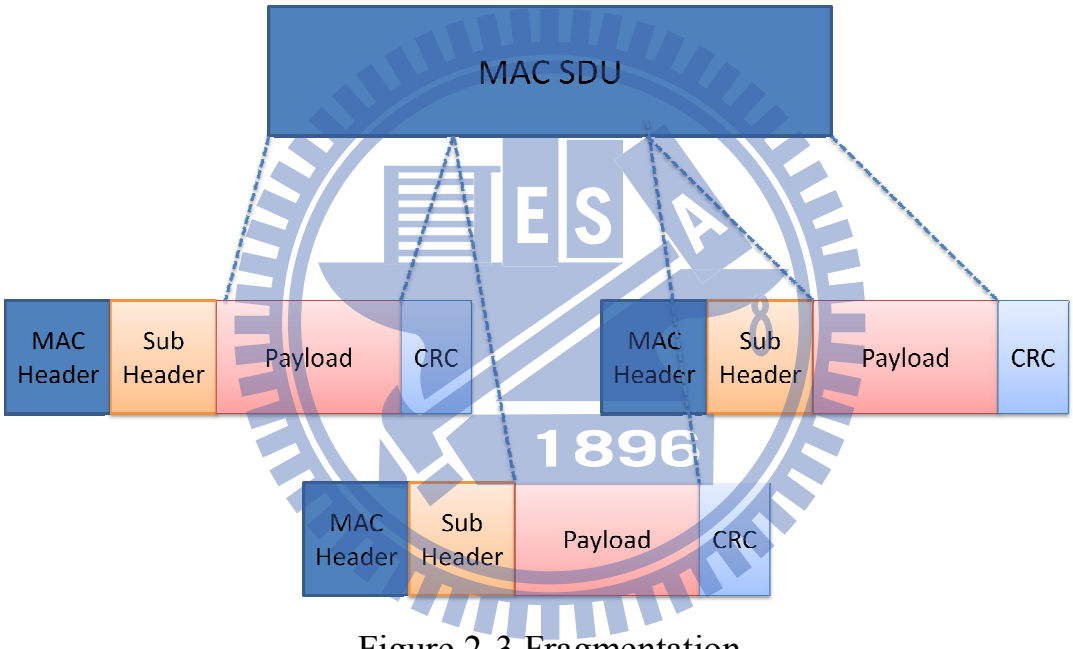


Figure 2-3 Fragmentation

If the channel condition is good enough, we may use the packing mechanism to combine multiple SDUs into one MPDU, as showed in figure 2-4. This could reduce the overhead and redundancy of transmission, because additional headers and CRCs will be eliminated.

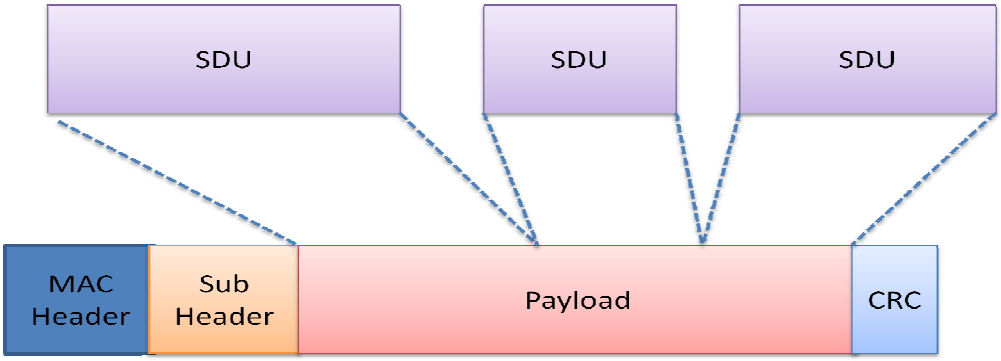


Figure 2-4 Packing

2.2.4 Qos-Based Service Classes

The WIMAX system provides five kinds of service classes. They are Unsolicited Grant Service (UGS), Real-time Polling Service (rtPS), Extended Real-time Polling Service (ertPS), Non-real-time Polling Service (nrtPS), and Best Effort Service (BE), they are described as follows:

1) Unsolicited Grant Service (UGS) : This kind of service is designed to support constant bit rate (CBR) transmission. It is used to support the real-time service with fixed-length packets, such as T1/E1 or the VoIP service without silence suppression.

2) Real-time Polling Service (rtPS) : This kind of service is designed to support real-time UL service flows with variable-size data packets on a periodic basis, such as Moving Picture Experts Group (MPEG) video. It can meet the constrain of uni-cast real time service.

3) Extended Real-time Polling Service (ertPS) : It is a scheduling mechanism that builds on the efficiency of both UGS and rtPS. The BS provides unsolicited unicast grants as in UGS, thus saving the latency of a bandwidth request. However, UGS allocations are fixed in size, whereas ertPS allocations are dynamic.

4) Non-real-time Polling Service (nrtPS) : As its name means, the nrtPS is designed for non-real-time service that can tolerate more delay, such as FTP, web-browsing and so on. It takes use of the transmission opportunities to transmit data.

5) Best Effort Service (BE) : The purpose of the BE service is to provide the effective service. Which means it provides reliable service instead of real-time service.

2.3 An Introduction To The 802.16e PHY

2.3.1 Overview Of 802.16e PHY

The purpose of the physical layer is to take use of the physical medium and to transmit real data bits. To meet the requirement, two different frequencies of standard are defined. Also, there are four kinds of PHY specifications defined in the 802.16 system. They are WirelessMAN SC, WirelessMAN SCa, WirelessMAN OFDM and WirelessMAN OFDMA. All above is showed in table 1-1.

Standard	Targeted frequency band	PHY	MAC	Duplexing
WirelessMAN-SC	10–66 GHz	SC	Basic	TDD, FDD
WirelessMAN-SC2	2–11 GHz	SC2	Basic+ARQ+STC+AAS	TDD, FDD
WirelessMAN-OFDM	2–11 GHz licensed	OFDM	Basic+ARQ+STC+DFS+AAS	TDD, FDD
WirelessMAN-OFDM	2–11 GHz unlicensed	OFDM	Basic+ARQ+STC+DFS+mesh+AAS	TDD
WirelessMAN-OFDMA	2–11 GHz licensed	OFDMA	Basic+ARQ+STC+DFS+AAS	TDD, FDD
WirelessMAN-OFDMA	2–11 GHz unlicensed	OFDMA	Basic+ARQ+STC+DFS+mesh+AAS	TDD

Table 2-1 802.16e PHY and MAC

In this thesis, we focus on the final one because the OFDMA system

provides more flexibility and efficiency than others for its two dimensional allocation. Besides, it can be operated on the non-line of sight (NLOS) environment. So it is also suitable for mobile communication and meets our requirement.

In the WIMAX system, data exchange between the BS and MS is in a frame-based structure. That is, the time axis is partitioned into many sub-frames, or slots. The transmission of data is in a TDMA, or TDD manner. Other than TDD, there is another scenario called FDD, which divides the medium based on the division of frequency. The TDD has many merits and is used in most case. FDD is often used in the residential case. In this thesis, we also adopt the TDD manner.

The PHY frame structure and some important mechanisms are introduced in the following sections.

2.3.2 PHY Frame And Framing Time Structure

The WIMAX PHY is also responsible for the resource management. The BS will dispatch the time slot to each user, which is the unit of framing time. Slots that are dispatched to a user are called the user's data region. The scheduling algorithm of PHY can help to better utilize the radio resource. But this out scope of this thesis.

The downlink sub-frame starts with a downlink preamble. The preamble contains information, such as the synchronization situation and the channel estimation that could be used by the PHY control unit. Followed the preamble is the Frame Control Header (FCH), which contains the information about the frame, for example, the MAP information, the modulation scheme and the available subcarrier. The MAP is divided into DL-MAP and UL-MAP as well. The MAP contains the whole picture of the users. An illustration of the PHY frame is