# CHAPTER 1

# Introduction

The IEEE 802.16 standard [1, 2] “Air Interface for Fixed Broadband Wireless Access Systems”, also known as WiMAX, targets at providing last-mile wireless broadband access in metropolitan area networks. IEEE 802.16 offers an alternative to cabled access networks, such as fiber optic links, DSL links. Furthermore, IEEE 802.16 is a wireless network, which has the high capacity to cover more broad geographic areas without the costly infrastructure development. The technology may prove less expensive to deploy and may lead to more ubiquitous broadband access [3]. The clients also can connect to the IEEE 802.16 by adopting various existing wireless solutions, such as IEEE 802.11 (WiFi). IEEE 802.16 provides a cheaper and more ubiquitous solution to connect home or business to Internet. Much attention was paid to the IEEE 802.16 issues in recent years and a lot of industries formed a WiMAX Forum in order to certify compatibility and interoperability of various 802.16 products.

A Markov Chain to model this distributed scheduling of mesh mode as well as a mathematical model are proposed in this thesis to evaluate the average delay time.

## 1.1. Background

The initial version of 802.16 was published in 2001. It supported the multiple frequency allocations at 10--66GHz for Line-of-Sight (LOS), initially. Single Carrier was designed in PHY during this period. Two years later, 802.16a was published in January 2003. The frequency allocations at 2--11GHz for non Line-of-Sight (NLOS) were interested, and three types of PHY, that OFDM, OFDMA and Single Carrier were included in this version. There was an 802.16d [1] published in 2004, as a revision of original 802.16, 802.16a and 802.16c, which was a version belong to the fixed broadband wireless access. In 2005, 802.16e was published to be an amendment to 802.16d on enhancement to support mobility [2].

General PHY knowledge introduced here makes us realize the IEEE 802.16 more concretely. Both TDD (time division duplex) and burst FDD (frequency division duplex) variants are defined as its access schemes. Adaptive modulations, such as BPSK, QPSK, 16-QAM and 64-QAM are applied. This scheme is very different from 802.11 that the fixed modulation is used. By the way, channel bandwidths of 20 or 25 MHz (typical U.S. allocation) or 28 MHz (typical European allocation) are specified. The data transmission rate is up to 130 Mbps/s. The typical transmission range is up to 30 miles (approximate to 50km). 802.16e promises to support mobility up to speeds of 70–80 mile/h (105 - 120 km/h)and an asymmetrical link structure that will enable the subscriber station to have a handheld form factor for PDAs, phones, or laptops [4].

Up to the global view of MAC (Media Access Control) layer, there are two modes defined in the IEEE 802.16, which are the PMP (point-to-multipoint) mode and the Mesh mode. PMP mode is like the traditional star topology, or like the infrastructure mode in the

802.11. Mesh mode is like the ad-hoc mode in the 802.11. The traffic from BS (Base Station) to SS (Subscriber Station) is called downlink subframe; opposite direction, from SS to BS is called uplink subframe. Contrary to the basic PMP mode, there are no clearly separate downlink and uplink subframes in the mesh mode. Only TDD is supported in the mesh mode base on the standard's definition. The BS and SS consists in the 802.16 network. The BS serves as the central gateway between 802.16 network and backhaul internet or another 802.16 networks. The SS plays the role of client in the 802.16 network.

The IEEE 802.16 defined the mesh frame structure as a convenience to organize the mesh network. The frame is divided into two subframes. One is the data subframe; the other is control subframe. The scheduling information and how many time slots in the data subframe it will request are specified in the control subframe. Understanding the scheduling of the control subframe is very useful to adjust the performance. That's why we focus on estimating scheduling of the control subframe in this thesis.

The 802.16 mesh mode topology is depicted as Figure 1.1. There are many SSs in this topology which terminals, such as PDAs, notebooks or cellular phones, can be connected to via 802.11 or other protocols. The mesh mode is organized throughout these SSs and BSs. The link coverage is expanded under mesh network. Certain SSs are responsible to connect to the BSs. By these BSs, they connect to the backhaul or internet.

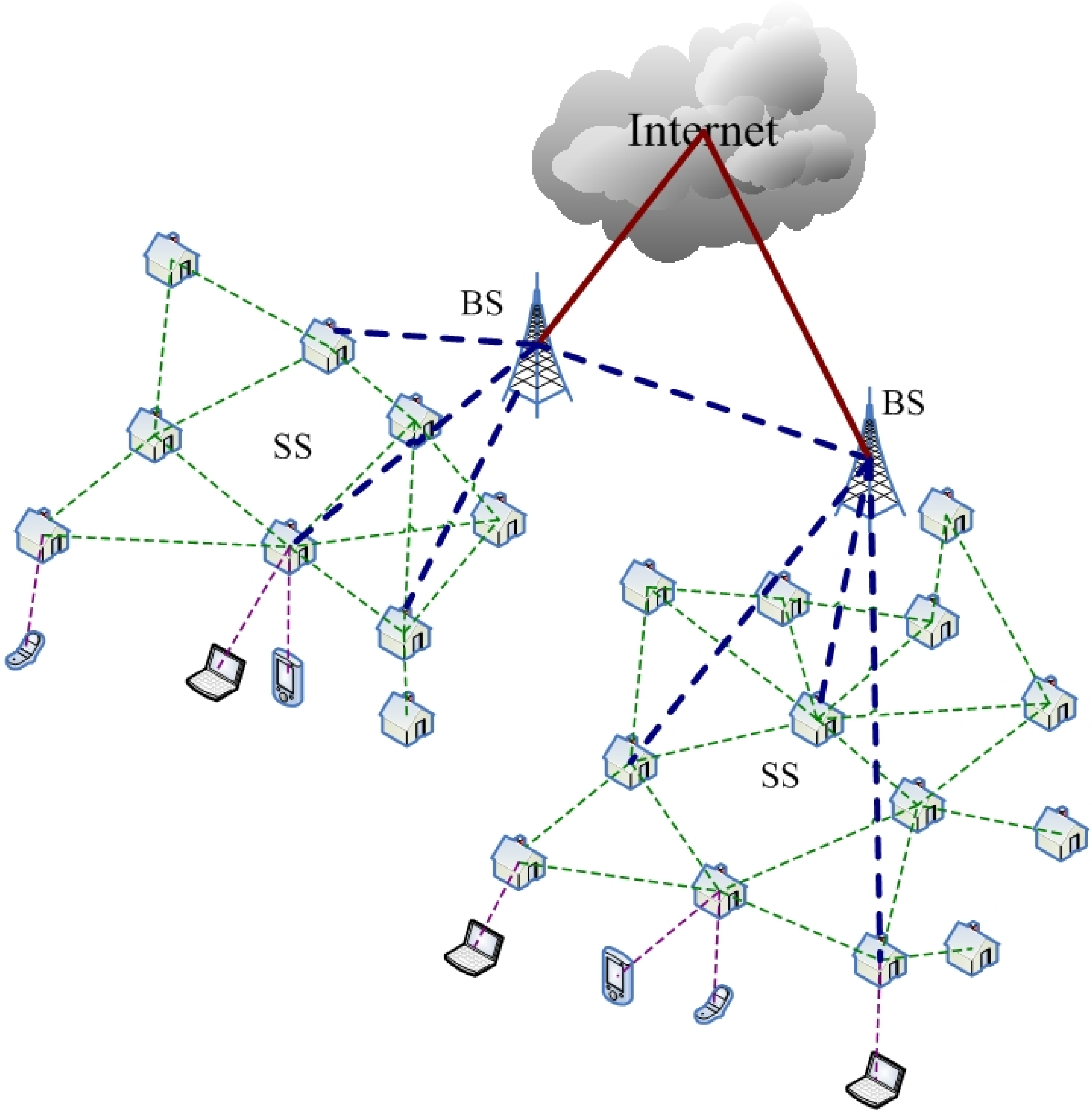


Figure 1.1: IEEE 802.16 Mesh Mode Topology

## 1.2. Motivation

More works on the IEEE 802.16 have primarily focused on the PMP mode. The BS is the key point in the PMP mode, because all of the flows from the SSs or to the SSs need pass through the BS. In that case, most of traffic controls depend on the BS. Naturally, it is responsible for the heavy loading throughout the PMP mode topology. It may bring about the risks with the paralysis of the network, if BS doesn't work smoothly. Nevertheless, each node in the mesh mode can act as the controller and partakes of the loading and the risks with the paralysis of the network.

The mesh mode is more complex, since there is no clear node as a centralized controller and every node competes for the channel in a distributed manner. Many interesting issues, such as selection of links, synchronization, routing, power saving …etc., are become more complex under mesh topology. All of these issues need a good performance in scheduling. So the scheduler and competing behavior become more important in the mesh mode. On the other hand, it is difficult to predict the system throughput and delay performance in the mesh mode without understanding the scheduler and competing behavior in control channel thoroughly.

We hope propose a easy and more quickly method to evaluate the delay time of scheduling control subframe.

## 1.3. Organization

The rest of this thesis is organized as follows. Chapter 2 introduces related work about the behavior and performance of the IEEE 802.16 mesh mode. The first reference Modelling and Performance Analysis of the Distributed Scheduler in IEEE 802.16 Mesh Mode is explained here. Chapter 3 proposes and explains our analysis of IEEE 802.16 distributed scheduling algorithm. We propose a Markov Chain to model this distributed scheduling and a mathematic method to evaluate the delay time in chapter 4. We verify the accuracy of the model by comparing delay time with the result in the simulation in chapter 5. And chapter 6 concludes this thesis and remarks on future work.