CHAPTER 1

Introduction

As the wireless network technology evolves, IEEE 802.16 standard, also known as WiMax, appears as a great competitor to GSM, 3G, even IEEE 802.11 networks. The technology is claimed to provide the bandwidth up to 70 Mbps, and 5 miles of service range at maximum. It is considered as a Wireless Metropolitan Area Network (WMAN) technology for its wide coverage. The PMP (Point-to-Multipoint) and mesh (or Multipoint-to-Multipoint) mode are provided in the standard. Both modes have the inherent QoS (Quality of Service) support.

IEEE 802.16 standard makes the definition mainly in Data link layer and a small part of Physical layer as well. In Data link layer, the Medium Access Control mechanism can be Time Division Duplex or Frequency Division Duplex. In Physical layer, the modulation method and spectrum allocation are defined. As a descendant of IEEE 802.11, IEEE 802.16 is very different from it for its bigger coverage and higher data rate. IEEE 802.16 is expected to have the following potential usage:

- Providing the wireless alternative to traditional cable or DSL lines for last-mile access.
- High bandwidth for mobile data and telecom services.
- Connecting WiFi hotspots, or, even replacing them.

Since IEEE 802.16 can serve as a replacement of current wired access networks, the variety of network applications shall be transmitted across the IEEE 802.16 networks. In mesh mode, the situation is even more complex, due to the cross-layer architecture is necessary. The real-time applications, such as voice or real-time video streams have different QoS requirements for bandwidth, delay, jitter, and packet loss. To better supporting QoS in mesh mode is a more challenging task than it is in the PMP mode.

1.1. Background

In this section, we make a description on the basic concepts of this work. The IEEE 802.16 family of standard is introduced in 1.1.1. The concept of wireless mesh networks is given in 1.1.2. And, how token bucket works shall be described in 1.1.3.

1.1.1. The History of IEEE 802.16 Standards

The first IEEE 802.16 standard was approved in 2001 [1], which is the original IEEE 802.16 standard. Three amendments of the standards are given before 2003, which are IEEE 802.16a, 802.16b and 802.16c, addressing the issues of radio spectrum, quality of service and inter-operability, respectively. By the year of 2004, IEEE 802.16d [2] was released. It aimed to include a/b/c amendments, and the inter-operability with HIPERMAN standards from Europe. In the standard of 802.16a, the functionality of meshing was added. In 802.16d, the mesh mode is reserved as an optional operation mode.

To promote and certify the compatibility and inter-operability of IEEE 802.16 products, the “WiMax Forum” has been setup by the industry group led by Intel. The relationship is similar to the WiFi Forum and IEEE 802.11 standards.

IEEE 802.16d does not support mobility. An amendment to the standard, IEEE 802.16e, addressing mobility support was concluded in 2005. IEEE 802.16e has drawn worldwide attentions and once has been considered as a threat to existing wireless communication systems. Recently, more and more people think that WiMax and current wireless systems, such as 3G and WiFi, should be complementary rather than competing.

Ideally, the bandwidth of IEEE 802.16 is 70 Mbps and the service radius is 5 miles. However, the bandwidth is shared by the users in a radio sector. If too many users share the bandwidth, each of them receives the reduced bandwidth. On the other hand, the service range depends on the transmission power, antenna and the height of the base station. However, currently, the WiMax still outperforms any existing wireless technologies.

The IEEE 802.16 standards still proceed to being established. The active amendment is 802.16f, which is about Management Information Base. The other Amendments in process are listed in Table 1.1.

Table 1.1: Amendments in Development.

802.16g	Management Plane Procedures and Services
802.16h	Improved Coexistence mechanisms
802.16i	Mobile Management Information Base
802.16j	Relay Task Group
802.16k	Network Management Task Group

We focus our research on the IEEE 802.16 mesh mode according to the standard of IEEE 802.16d [2].

1.1.2. The Wireless Mesh Networks

Wireless Mesh networks (WMNs) comprises wireless nodes that serve as routers and source of data packets. The nodes in WMNs have minimum mobility and form a network backhaul one another. The WMN is actually a special form of ad hoc network, where packets are sent on a multi-hop basis. WMN is dynamically self-organized and self-configured, as the connectivity between the nodes are established and maintained automatically. The architecture is shown in Figure 1.1. The nodes with wired connection to the internet is generally called “gateway”, the user-end node is called “mobile hosts”, and the other nodes are “wireless routers”. In a more randomized wireless mesh networks, user nodes serve as wireless routers as well.

WMN is considered to have the following advantages:

- Robustness
- Reliable
- Scalability
- Fault tolerance
- Wider service coverage
- Considerable low cabling cost.

A good WMN solution is composed of protocols across the layer 1 and layer 4. Routing protocol and MAC protocol are especially important factors that affects performance of the WMN. Existing protocols and researches from wireless networks, ad hoc networks, or even wireless sensor networks are revisited and re-enhanced by the researchers. We also focus our research on these two layers. In MAC layer, standards across MAN, LAN (Local Area Network) and PAN (Personal Area

Network) are trying to, or already include the meshing functionalities, such as 802.11s, 802.15.5 and 802.16.

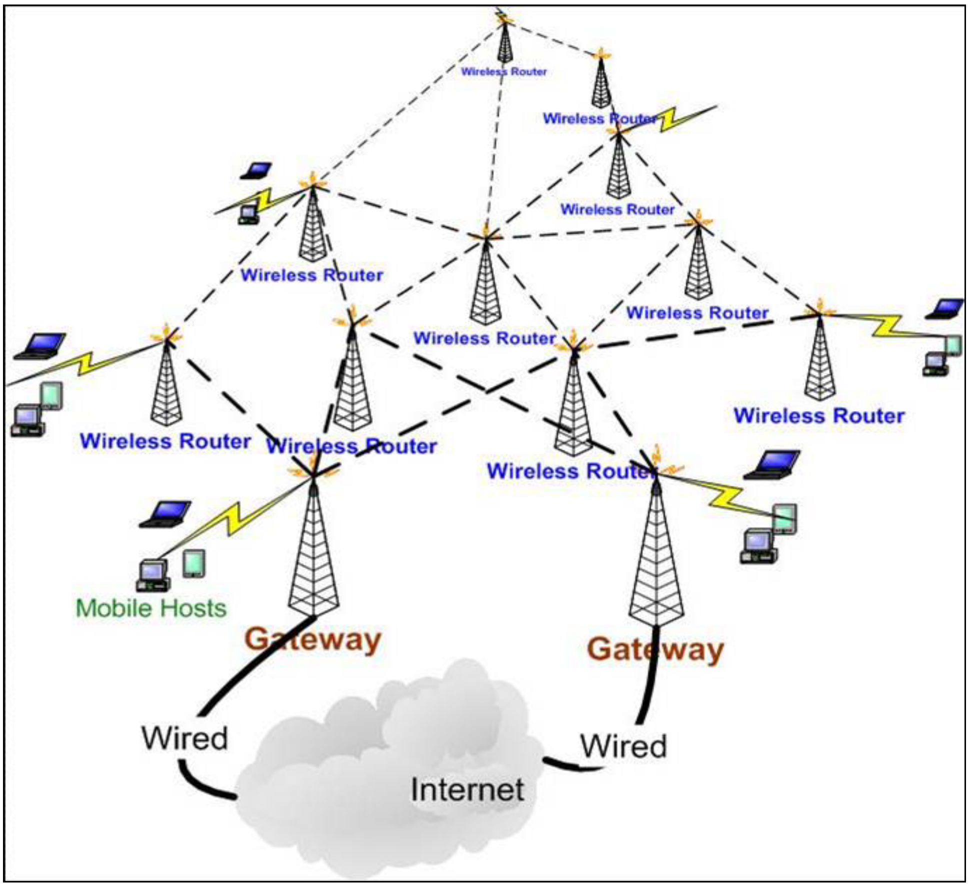

Figure 1.1: The Architecture of WMN.

Currently, the MAC layer of most wireless mesh network solutions are based on IEEE 802.11 standards. For example, the Roofnet [3] is an academic WMN solution by MIT. However, since medium access control mechanism of IEEE 802.11 is CSMA/CA (Carrier Sense Multiple Access/ Collision Avoidance), if IEEE 802.11 protocols are chosen as MAC protocols in WMNs, the QoS is difficult to guarantee. That is, all traffic flows will be treated as best-effort ones. The traffic flows with bandwidth or delay requirement will receive low performance. However, IEEE 802.16 mesh mode has the inherent QoS support in MAC layer, QoS and admission control can be better provided with appropriate modification. The details of IEEE 802.16 mesh mode will be further described in Chapter 2.

1.1.3. Token Bucket Mechanism

Token bucket mechanism is often used to control the rate of packets that are injected into the network. It works well for the “bursty” traffic. Two parameters are necessary for this controlling mechanism: bucket size *B*, and token rate *r*. The token bucket mechanism is depicted in Figure 1.2.

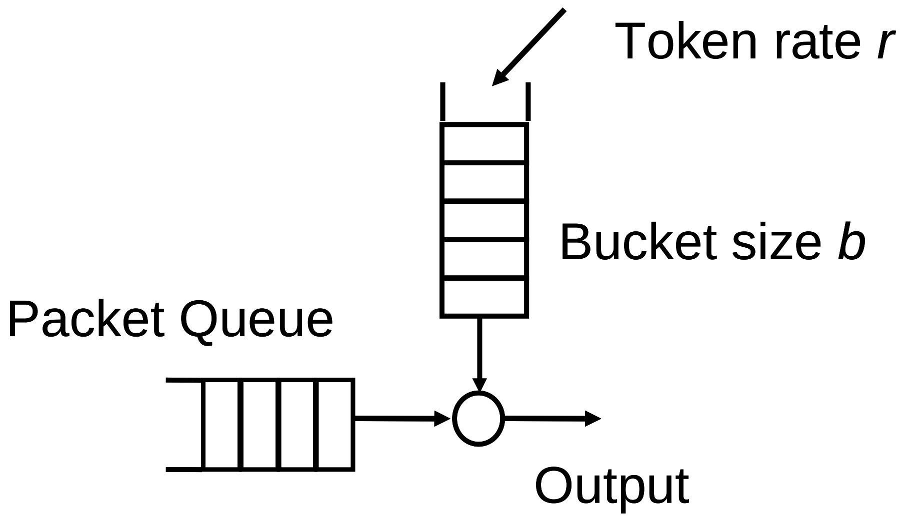

Figure 1.2: Token Bucket Mechanism.

The token bucket contains bucket of tokens which is produced at rate *r*. Each token represents a unit of bytes or a packet data unit (PDU) at network layer. When a packet is generated, it will be first put in the packet queue. A packet is not allowed to be transmitted until it possesses a token. If there is no packet generated, the packet queue would be empty and the produced token will be stored in the token bucket. When the token bucket is full, the newly-produced token would be discarded.

For a Bursty traffic, when the packets are generating at the peak rate μ, which is bigger than the token rate *r*. The token stored in the token bucket is consuming at the rate $\mu - r$. Finally, when the token stored in the bucket is completely consumed, the traffic rate injected to the network would be dropped as low as *r*. Therefore, a bursty traffic can be tamed using a token bucket mechanism.

Assume that a traffic flow is under the control of the token bucket mechanism. Within a time duration *t*, the maximum volume of data that can be transmitted is:

$$r*t + b$$

, where *r* and *b* are token rate and bucket size respectively. With all these information, the bandwidth within this duration can be calculated as:

$$\frac{r*t+b}{t}$$

Using the token bucket mechanism, bandwidth can be estimated by just two parameters, and the bursty traffic can be well dealt with.

1.2. Motivation

In PMP and mesh modes of IEEE 802.16, call admission control is not defined and left as an open issue. In the previous work [4], the call admission control and packet scheduling for PMP mode has been discussed. However, in mesh mode, QoS is more difficult to guarantee than PMP mode due to its ad hoc nature. Providing QoS and implementing admission control can be more challenging and interesting in mesh mode. Therefore, a call admission control algorithm with the modification of the well-known token bucket mechanism is proposed along with a simple static routing metric and algorithm.

1.3. Organization

The rest of this thesis is organized as follows. Chapter 2 introduces the details of IEEE 802.16 standards and focuses on the mesh mode. The related work is listed in Chapter 3. Chapter 4 describes the proposed routing metric and CAC algorithm. Chapter 5 validates our algorithms by simulations experiments. Finally, Chapter 6 concludes this thesis and remarks on the possible future works.