CHAPTER 1

Introduction

The idea of mobile computing service is to provide a ubiquitous information environment. Users can access network connectivity through all kinds of wired or wireless networks anywhere and anytime. The rapid development of mobile computing makes such dream round the corner. However, the present mobile ad hoc networks (MANET [25]) still can't support real-time multimedia transmission very effectively. In other words, the capability of supporting QoS (Quality of Service) guarantee service has become a very important issue. IEEE 802.11 PCF [1] [2] adopts the polling scheme to provide time-bounded traffic service, which requires an infrastructure and is not suitable in multi-hop wireless networks. Moreover, due to mobility and traffic dynamics, the network resource management is more difficult in mobile ad hoc networks, than in static wired networks. Thus, QoS support in such an environment is a challenge. Here we introduce some background knowledge of 802.11 multi-hop wireless networks and QoS concepts first.

1.1 Background

IEEE 802.11 MAC protocol provide two different access methods, including the distributed coordination function (DCF), and the point coordination function (PCF). Here we discuss

DCF only because PCF is only usable on infrastructure network configurations.

1.1.1 Distributed Coordination Function (DCF)

DCF is the fundamental access method of the IEEE 802.11 MAC protocol and is know as carrier sense multiple access with collision avoidance (CSMA/CA). For a mobile station to transmit, it shall sense the medium to determine of another mobile station is transmitting. A transmitting mobile station shall ensure that the medium is idle for a DIFS (DCF interframe space) before attempting to transmit. If the medium is determined to be busy, the mobile station shall defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the mobile station shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. The basic access mechanism is illustrated in Figure 1-1.

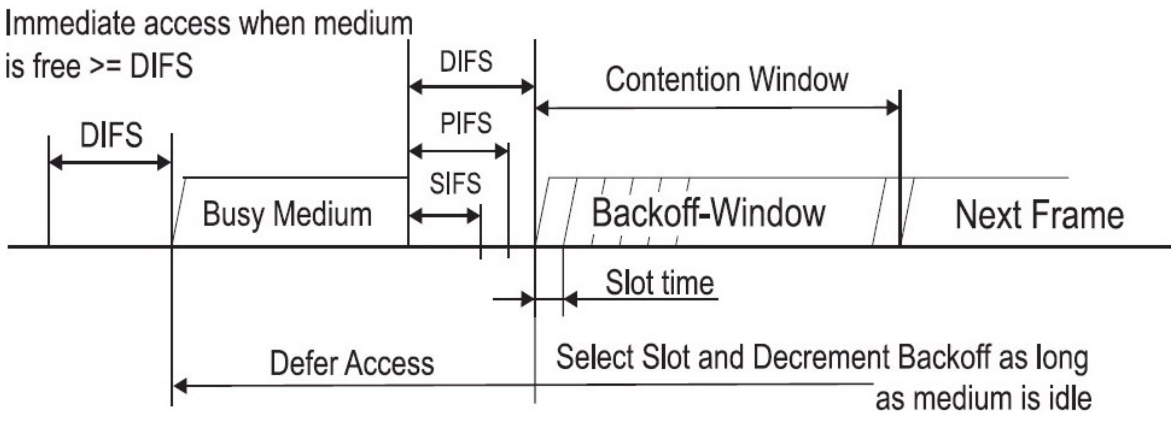

Figure 1-1: Basic access method.

The backoff procedure shall be invoked for a mobile station to transfer a frame. A mobile station performing the backoff procedure shall use the carrier-sense mechanism to determine whether there is activity during each backoff slot. If the medium is determined to be busy at any time during a backoff slot, then the backoff procedure is suspended; that is, the backoff timer shall not decrement for that slot. The medium shall be determined to be idle for the duration of a DIFS period or EIFS, as appropriate, before the backoff procedure is allowed to resume. Transmission shall commence whenever the backoff timer reaches zero. When multiple mobile stations are deferring and go into random backoff, then the mobile station selecting the smallest backoff time using the random function will win the contention. The reception of some frames, requires the receiving mobile station to respond with an acknowledgement, generally an ACK frame. In the case of successful acknowledged transmissions, this backoff procedure shall begin at the end of received ACK frame. Figure 1-2 depicts the backoff procedure.

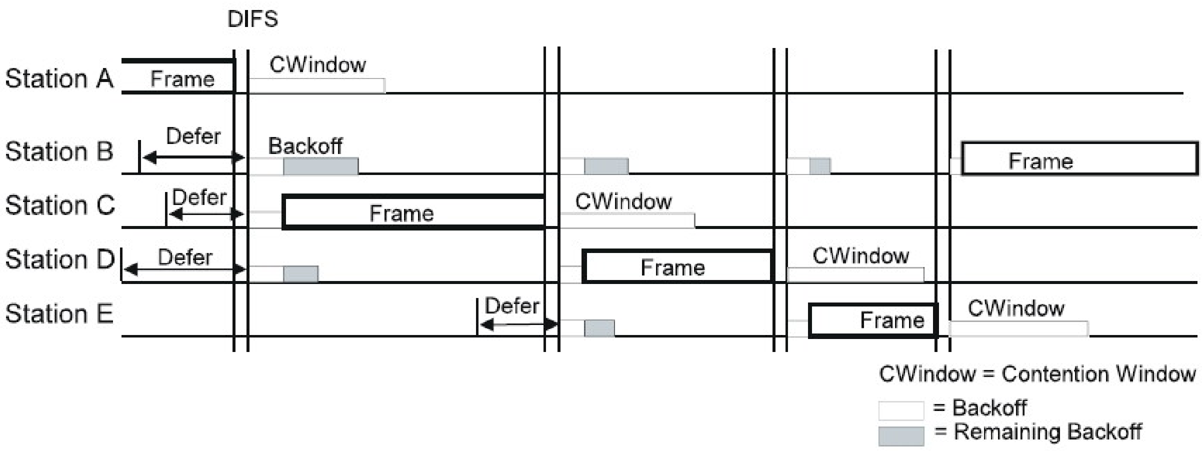

Figure 1-2: Backoff procedure.

1.1.2 RTS/CTS and NAV mechanism

The CSMA/CA protocol is designed to reduce the collision probability between multiple mobile stations accessing a medium at the same time. To eliminate this problem, IEEE

802.11 MAC defines RTS/CTS (Request to Send/Clear to Send) mechanism. Before a mobile station transmitting its data frame, it transmits a RTS control frame to reserve the channel first. When receiving station receives the RTS frame, it responds CTS frame. Only when the transmitting station receives the CTS frame correctly which represents that the RTS frame sent by the transmitting station didn't collide, it is allowed to transmit its frame. All other mobile stations terminate transmitting either when they receive RTS or CTS frames; therefore it lowers the collision probability greatly.

A virtual carrier-sense mechanism shall be provided by the MAC. This mechanism is referred to as the network allocation vector (NAV). The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames prior to the actual exchange of data. The carrier-sense mechanism combines the NAV state and the mobile station's transmitter status with physical carrier sense to determine the busy/idle state of the medium. Mobile stations receiving a valid frame shall update their NAV with the information received in the Duration/ID field, but only when the new NAV value is greater than the current NAV value and only when the frame is not addressed to the receiving mobile station.

Figure 1-3 indicates the NAV for mobile stations that may receive the RTS frame, while other mobile stations may only receive the CTS frame, resulting in the lower NAV bar as shown (with the exception of the mobile station to which the RTS was addressed).

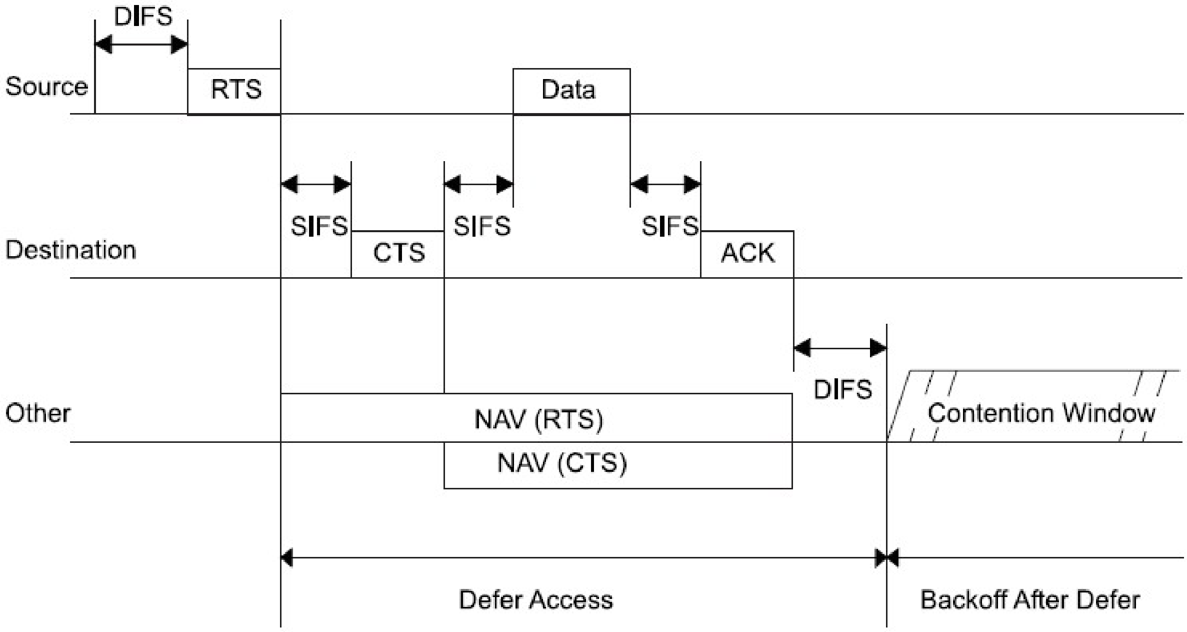

Figure 1-3: RTS/CTS/data/ACK and NAV setting.

1.1.3 Ad Hoc Wireless Networks

The ad hoc wireless networks, consisting of a collection of wireless nodes, all of which may be mobile, dynamically create a wireless network among themselves without using any infrastructure or administrative support [3] . Ad hoc wireless networks are self-creating, self-organizing, and self-administering [4] . The ad hoc wireless networks offer unique benefits and versatility for certain environments and certain applications. No preexisting fixed infrastructure, including base stations, being prerequisite, they can be created and used "any time, anywhere". Second, such networks could be intrinsically fault-resilient, for they do not operate under the limitations of a fixed topology. Indeed, since all nodes are allowed to be mobile, the composition of such networks is necessarily time-varying.

Figure 1-4 is an ad hoc wireless network diagram. We can see that there is a local area network formed from MH3 to MH7; MH3 must transmit data to MH7 through other intermediate mobile hosts between them because MH7 is not in the transmitting range of MH3. That is, MH3 would successfully transmit data through MH6 (or MH4) and MH5 to MH7. Indeed, a distinguishing feature of ad hoc networks is that all nodes must be able to function as routers on demand.

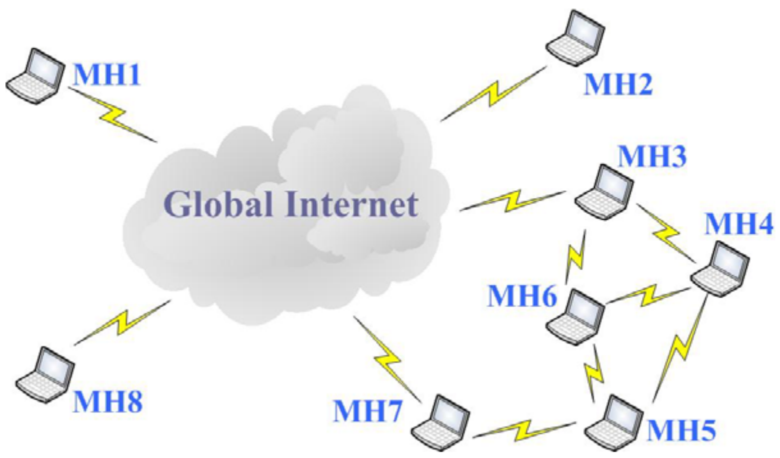

Figure 1-4: Ad Hoc Wireless Networks.

An ad hoc network begins with at least two nodes broadcasting their presence (beaconing) with their respective address information. The distinct topology updates, consisting of both address and route updates, are made in all these nodes immediately afterward. The mobility of nodes may cause the reachability relations to change in time, requiring route updates. As more nodes join the network or some of the existing nodes leave, the topology updates become more numerous, complex, and usually more frequent, thus diminishing the network resources available for exchanging user information.

Numerous challenges must be overcome to realize the practical benefits of ad hoc networking. These include effective routing, medium access, mobility management, power management, security, and QoS issues, mainly pertaining to delay and bandwidth management. Cost-effective resolution of these issues at appropriate levels is essential for widespread general use of ad hoc networking.

1.1.4 Quality of Service

The notion of QoS, as mentioned before, is a guarantee by the network to satisfy a set of predetermined service performance constraints for the user in terms of the end-to-end delay statistics, available bandwidth, probability of packet loss, and so on. The cost of transport and total network throughput may be included as parameters. Obviously, enough network resources must be available during the service invocation to honor the guarantee. The first essential task is to find a suitable path through the network, or route, between the source and destination(s) that will have the necessary resources available to meet the QoS constraints for the desired service. The task of resource reservation is the other indispensable ingredient of QoS.

QoS is a set of service requirements to be met by the network while transporting a packet stream from source to destination. To attain and preserve the service attributes for this connection, the network must guarantee the availability of a set of resources associated with the flow. QoS guarantees can be attained only with appropriate resource reservation techniques, and the most important element among them is QoS routing, that is, the process of choosing the routes to be used by the flow of packets of a logical connection in attaining the associated QoS guarantee.

1.1.5 MANET QoS

QoS for ad hoc networks is a challenging area of research; much remains to be done. In wireless networks, because nodes cannot receive and transmit packet at the same time (due to peer to peer communication capability, the same frequency band is used for both transmitter and receiver), a node cannot send or receive message concurrently from any other node in the same time slot, otherwise it will cause collision. Path bandwidth calculation turns out to be much more complicated in a wireless environment than in a wired one.

According to IEFT RFC2501 [25] , the characteristics of MANET (Mobile Ad hoc Networks) include dynamic topologies, bandwidth-constrained, variable capacity links, energy-constrained operation, and limited physical security, etc. Bandwidth in ad hoc networks is hard to control, because the variation in bandwidth not only affects the link, but also influences the range around the link. Like Figure 1-5, bandwidth of E, F, G would be influenced when the path bandwidth of A to D through B, C changes.

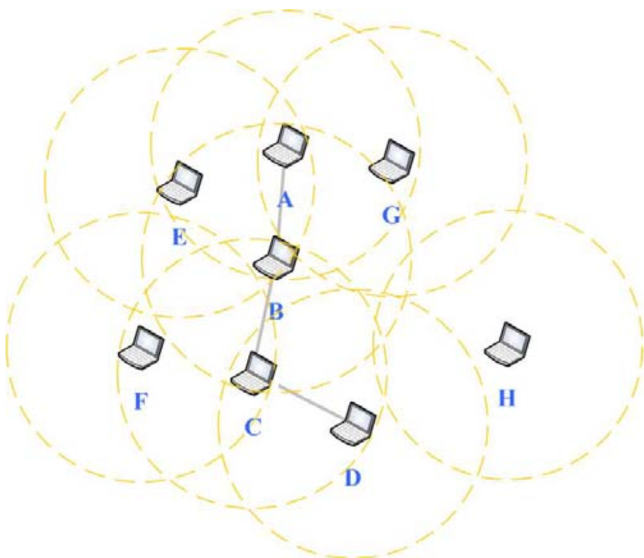

Figure 1-5: Bandwidth Affection in Ad Hoc Wireless Networks.

We hope that the mobile ad hoc networks could support real-time multimedia transmission effectively. But due to mobility and traffic dynamics, the network resource management is more difficult in mobile ad hoc networks, than in static wired networks. Thus, QoS support in such an environment is a challenge.

In IEEE 802.11 wireless multi-hop networks, each node uses DCF to randomly contend for the medium access to transmit packets, but there is multimedia transmission that needs QoS guarantees. IEEE 802.11 PCF adopts the polling scheme to provide time-bounded traffic service, which requires an infrastructure and is not suitable in multi-hop wireless networks. 802.11e [24] [18] provides differentiations of MAC access (EDCF), which introduces the concept of access categories (ACs, classification of IFS and contention window). The goal of EDCF is to provide a distributed access mechanism to support service differentiation. In EDCF, data packets are delivered through multiple backoff instances within one mobile station. A single mobile station may implement up to 4 transmission queues and each transmission queue uses a specific AC for contending the channel access. But it still remains random manner and can not guarantee the end-to-end ad hoc QoS in this network to meet requirements like bandwidth, delays, or jitters.

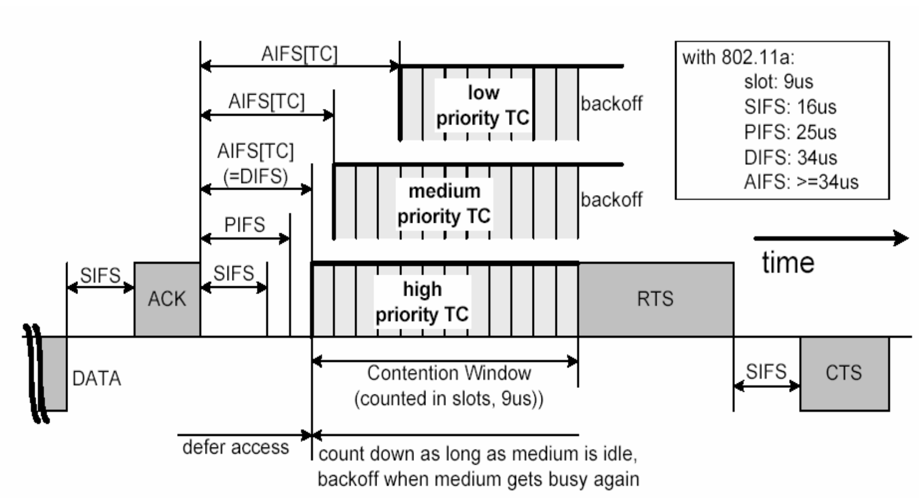

Figure 1-6: IEEE 802.11e protocol.

Figure 1-6 for illustration of the EDCF parameters.

1.2 Motivation

Bandwidth management is the most important issue of QoS support for time-bounded services. Path bandwidth calculation is the first key element to do this. It is not easy to choose a guaranteed bandwidth routing path to support bounded delay service because bandwidth is very dynamic. The reasons are as followed: (i) Changes of network topology will make link bandwidth down to zero in a very short time. (ii) The increase of a link load not only makes its own bandwidth decrease, but also affects the link bandwidth around it.

To support QoS in wireless networks, we have to consider the following problems:

1. Link bandwidth is unknown: it’s not easy to detect bandwidth of each link.
2. Bandwidth usage is not easy to be calculated.
3. Rerouting due to node mobility.
4. We must also consider drop policy at each node.

In this thesis, we utilize load statistics to estimate current remaining network (link, path) bandwidth. Previous papers regarding bandwidth routing focused on TDMA to do bandwidth reservation. It is very complicated both in path bandwidth calculation and in reservation. Our solution can estimate bandwidth easily and quickly not only in TDMA networks, but also in IEEE 802.11 networks. Furthermore, our proposed method of path bandwidth calculation is robust to node mobility and traffic dynamics with sacrifice of little statistical errors.

1.3 Organization

The rest of this thesis is organized as follows. Chapter 2 introduces related works about providing QoS using bandwidth routing in mobile ad hoc networks and some problems they suffered. Chapter 3 presents our proposed Call Admission Control Scheme including the architecture, path bandwidth calculation, bandwidth routing, and bandwidth flow control. Simulation results using NCTUns network simulator are given in Chapter 4. Chapter 5 concludes this thesis and remarks on future work.