Abstract

Speaking of Wireless LAN, the general thought is about data transfer while using applications such as web browser, e-mail client, etc. As the technology is advancing, Wireless LANs are now also capable of supporting time-sensitive services such as voice and video. These services have stringent service requirements from the network infrastructure. These requirements supersede the requirements of general traffic data. The protocols used for such services are Enhanced Distributed Coordination Function(EDCF) and Hybrid Coordination Function(HCF). To get a better understanding of these protocols, we will also understand Distributed Coordination Function(DCF) and Point Coordination Function(PCF).

1 Introduction

Wireless LANs are finding their way in all the verticals of life. More and more places, hospitals, airports are getting outfitted with them. Wireless medium is a shared medium, so as more and more devices demand the bandwidth, concentrating on performance becomes criticial. As the wireless LANs are giving a competition to the ethernet, apart from speed it will also have to assure the Quality of Service, specially when dealing with voice, video and other real time services. These services are very sensitive to time delays, so extra care has to be taken while dealing with these. In this report, we will talk about the standard protocols and the enhanced protocols to provide support for such services.
In this report, we will first talk about Wireless LAN in section 2. Secondly, we will look upon what is Quality of Service(QoS). Then, we will understand the basic protocols DCF and PCF in section 4 followed by discussion on their enhanced versions in section 5. In section 6, we will talk about Traffic Categories. Finally, summary and conclusion in section 7.

2 Wireless LAN

The traditional LANs are based on twisted pair, coaxial cable, and optical fiber. Wireless LAN serves the same purpose as that of a wired or optical LAN: to convey information among the devices attached to the LAN. But with the lack of physical cabling to tie down the location of a node on a network. Thus, the network can be much more flexible, as moving a wireless node is always easier. Wireless LANs have a number of other advantages. It helps in case the physical makeup of a building does not allows to run wires in it. It is also more robust against disasters such as earthquake and fire. But nothing comes without a price. It has certain disadvantages too. One of the major concern is the low speed that WLANs provide. Earlier it was around 1-1.5 Mbps, the upcoming protocols are promising speed as high as 54 Mbps. Apart from that, Products based on wireless technology have to follow many national restrictions. For eg. the frequency band available for transmission might not be common for all countries. Hence, it takes a long time to establish any global solution.

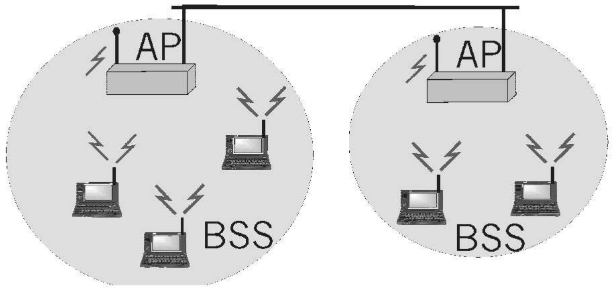

Figure 1: Example of wireless infra-structure

In a typical WLAN configuration, a transmitter/receiver device, or Access Point(AP), connects to the wired network from a fixed location using standard Ethernet cable. The access point receives, buffers and transmits data between the components of the WLAN (laptops, printers, handheld devices and other wireless equipment) and the wired network infrastructure. A single access point can support a small group of users and can function within a range of less than 100 to several hundred feet. The access point can be installed anywhere in the facility as long as good radio coverage is achieved.
Basic Service Set(BSS) is a set of 802.11 compliant stations that operate as a fully-connected wireless network. Generally, BSS comprises to an Access Point and a number of stations associated with it.
Now there arises a need to have a common protocol between the wireless client and the access points. 802.11 refers to a family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients.

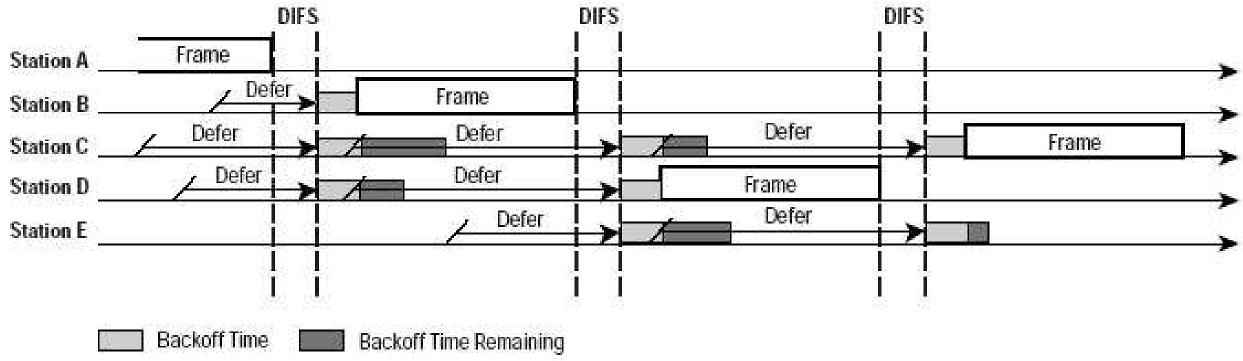

Figure 2: DCF Example, from [3]

3 QoS : Quality of Service

"Quality of Service (QoS) refers to the capability of a network to provide better service to the selected network traffic over various network technologies. QoS manages time-sensitive multimedia and voice application traffic to ensure that this traffic receivess higher priority, greater bandwidth and less delay than the best-effort data traffic." – *[3]*
QoS technologies provide the building blocks for voice and multimedia operations. Hereonward in this report whenver we refer to QoS, we inherently mean suppor for voice and other time-sensitive services. This quality is determined by certain factors such as

- Latency : Amount of time it takes a packet to reach the receiver after being transmitted from the sender. Also termed as "end-to-end delay".
- Jitter : Difference in the end-to-end latencies between various packets.
- Loss : A comparative measure of packets successfully transmitted and received to the total number transmitted.

One of the role of QoS is to keep delay, jitter and loss for selected traffic types within acceptable bounds. For eg. some of the constrains that must be maintained while transmitting voice are

1. Loss should not be more than 1
2. One-way latency should not be more than 150 - 200 ms.
3. Average jitter should be no more than 30 ms.

4 802.11

Before trying to understand the protocols that support QoS, we first lookover the 802.11 MAC protocol and discuss the limitations in it for QoS support. 802.11 protocol features two modes of operation: Distributed Coordination Function(DCF) and Point Coordination function(PCF). DCF allows independent and distributed channel access whereas PCF requires a dedicated station which provides a centralized channel arbitration. Let us look at these in detail.

4.1 Distributed Coordination Function (DCF)

DCF works on a listen-before-talk scheme, based on the Carrier Sense Multiple Access (CSMA) scheme. Any station first detects whether there is any transmission going on in wireless medium (listen), and only on finding it free it transmits (speak). However, if two stations detect the medium to be free at the same time, collision can take place. Thus, 802.11 defines a Collision Avoidance (CA) mechanism. As per this mechanism, everyone has to wait for a random time before speaking to avoid collision i.e. a station performs a random backoff procedure before starting. Every station has to keep sensing the channel for a random time after detecting the channel being idle for a minimum duration called DCF InterFrame Space (DIFS).
DCF access method is summarized in figure 2. When using DCF, a station first senses the medium to determine whether any transmission is going on or not. If it finds the medium to be idle for more thamDIFS, station proceeds with its transmission. However, if the medium is found busy, transmission is defered till current ongoing tansmission terminates. A random interval called the backoff interval, is then selected and

used to initialize the backoff timer. This backoff timer is decreased as long as the channel is idle and stopped when any transmission is going on. The decrement again starts when the channel is found to be idle for time > DIFS. The stations that defered from channel access due to channel being busy do not select a new random backoff time, but continue to count down the time of the defered backoff in progress. In this way, the station whose backoff time was larger than others is given more priority as time grows. A station transmits when its backoff timer reaches zero.
The backoff time is chosen in the interval (0,CW-1) defined as Backoff Window(Contention Window). Contention Window consists of two parameters

- CW_{min}
- CX_{max}

Initially the random number is between 0 and CW_{min}. If the initial random backoff expires without successfully sending the frame, the retry counter is incremented and the value of the random backoff window size is doubled. This doubling in size continues till the size reaches CW_{max}. The retries continue until the maximum retries or TTL(Time to Live) is reached.
For each successful reception of a frame, the receiving station acknowledges by sending an acknowledgement frame(ACK) immediately. In case, if after sending a frame, ACK is not received, transmission is assumed to be unsuccessful. After any such unsuccessful attempt, another backoff is performed with a double size of CW. Even after a successful transmission, the transmission-completing station performs a random backoff, even if there is no other pending frame to be delivered.
This complete model has inherent problem of hidden station as shown in figure 3.

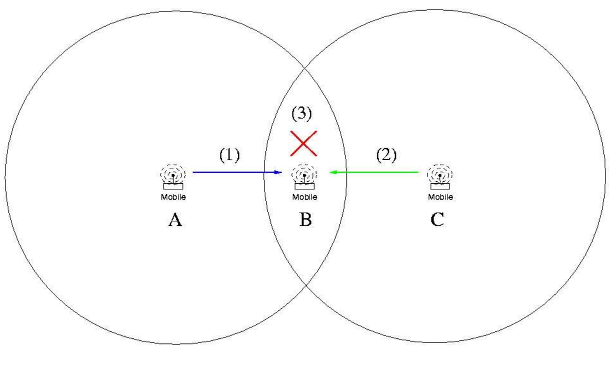

Figure 3: Hidden Station Problem

Hidden Station Problem: As shown in figure, station B wants to transmit to station C but is not able to do so because of interference of station 'A'. Station 'A' is the hidden station.
To solve this problem of hidden station, 802.11 defines a Request-to-Send/Clear-to-Send (RTS/CTS) mechanism. As per this mechanism, before transmitting data frames, every station has the option of transmitting a RTS frame which has to be followed by CTS transmission by the receiving station. The RTS and CTS frames contain the projected length of the transmission and thus inform all stations within the range of both stations how long the channel will be used. Thus, rest all stations including the hidden stations will not start any transmissions for that time interval. Here important data frames, such as ACK and CTS wait for an interval shorter than DIFS. This interval is called Short InterFrame Space (SIFS). There is no random backoff while using SIFS, as during such time multiple stations would not be trying to send the data frames at same time. SIFS provides a short and deterministic delay for frames that must go as quickly as possible. Clearly, SIFS is not available for use for data frames. Only management and control frames use SIFS.

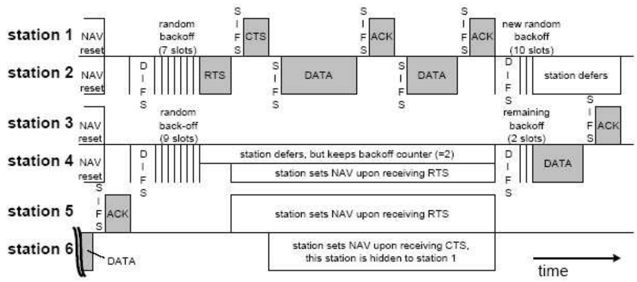

Figure 4: DCF with RTS/CTS mechanism, from [1]

4.2 Point Coordination Function (PCF)

PCF was designed to support time bounded services in a wireless LAN. In PCF all the coordination is done by a central coordinator called a Point Coordinator (PC). The PC is indeed an access point and has priority control of the medium. The PC uses PCF Interframe Space(PIFS). Since PCF has higher priority, PIFS is shorter as compared to DIFS. Time is divided into repeated periods called superframes. A superframe comprises of a Contention Free Period(CFP) followed by a Contention Period(CP). During the CFP, PCF is used for accessing the medium while DCF is used during CP.
A superframe starts with a beacon frame. This is a management frame which notifies all other stations ex-

cept the one being polled, not to initiate transmission for the length of CFP. This frame maintains the synchronization of the local timers in the stations and delivers protocol related parameters. In PCF mode, PC uses a Round-Robin scheduler to poll stations in a wireless cell. While polling, if PC has pending data for the station, then it combines the data and the CF-poll frame. Upon being polled, along with data, polled station sends ACK to notify successful reception. If PC receives no response from a polled station within PIFS, it polls the next station, or ends the CFP.

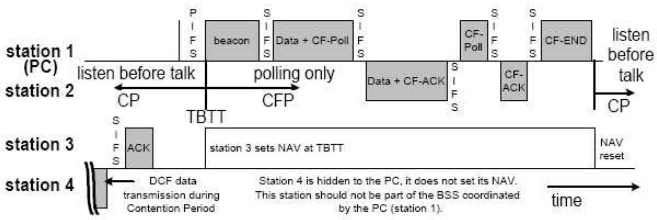

Figure 5: Point Coordination Function, from [1]

There are certain problems with 802.11 PCF mechanism.

- During the Contention Period, if the access point is prevented from accessing the channel due to busy medium, then this can result in foreshortened CFP. A CFP is foreshortened by the amount of delay caused by preceding transmission in CP.
- On being polled, a station can transmit frames of any length between 0 and 2312 bytes. Thus, the transmission duration of any polled station is unknown. Due to variable payload and duration needed for transmission, all stations might not be polled by PC in one cycle. Stations not being polled have to postpone their frames causing additional delay.
- A hidden station which missed the beacon frame will not stop its operation based on DCF. It might cause collision as it will not set the Network Allocation Vector(NAV).

5 802.11e : QoS support

802.11e is the enhancement of 802.11 that deals specifically with QoS. Enhancements have been done in both the modes to support QoS. Stations which operate under 802.11e are called enhanced stations. One important feature of 802.11e is Transmission Oppurtunity (TXOP). A TXOP is the interval of time during which a station has the right to initiate transmission. It is defined by the starting time and the duration.
The enhancement to DCF mode is called Enhanced DCF(EDCF) and to PCF is called Hybrid Coordination Function (HCF). Let us look at these in detail.

5.1 Enhanced Distributed Coordination Function

To support QoS, what is required is to give priority to certain traffic over other traffic. This support is realized with introduction of Traffic Categories(TC). For eg. Let us say that voice is in one category and background data transfer is another category. We give a priority to voice over background data transfer so as to transmit voice with lesses delay and jitter as it is more sensitive to these.

The way this can be achieved is by increasing the probability of a smaller random backoff while trying to access the medium. Thus, the enhancement is the liberty to adjust CW_{min}, CW_{max} and other parameters according to the Traffic Category.

Just as we defined SIFS for management and control frames to give them higher prioriy, here we define different Interframe Space for each category. This is known as Arbitration Interframe Space which depend upon Traffic Category. This prioritization is implemented within a station. Each TC within a station contests for a TXOP and independently starts a backoff after detecting channel being idle for Arbitration Interframe Spaces(AIFS). AIFS is atleast DIFS and can be enlarged individually for each TC. Just like with DIFS, after waiting for AIFS, each station sets a random backoff number in the Contention Window size. The minimum Contention Window size, $CW_{min}\,[TC]$ is also now dependent on TC. Clearly higher priority traffic will have smaller contention window and will have more chances to gain access to channel due to smaller backoff. Recall that in legacy DCF, after unsuccessful transmission, the size of Contention Window used to

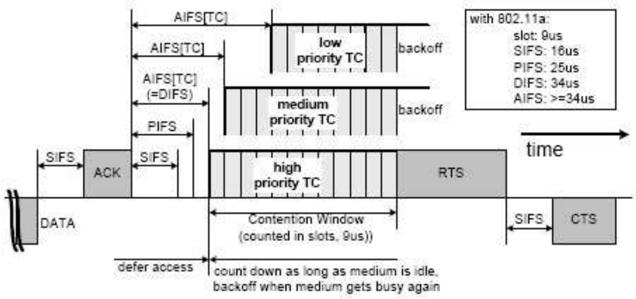

Figure 6: Interframe Spaces from [3]

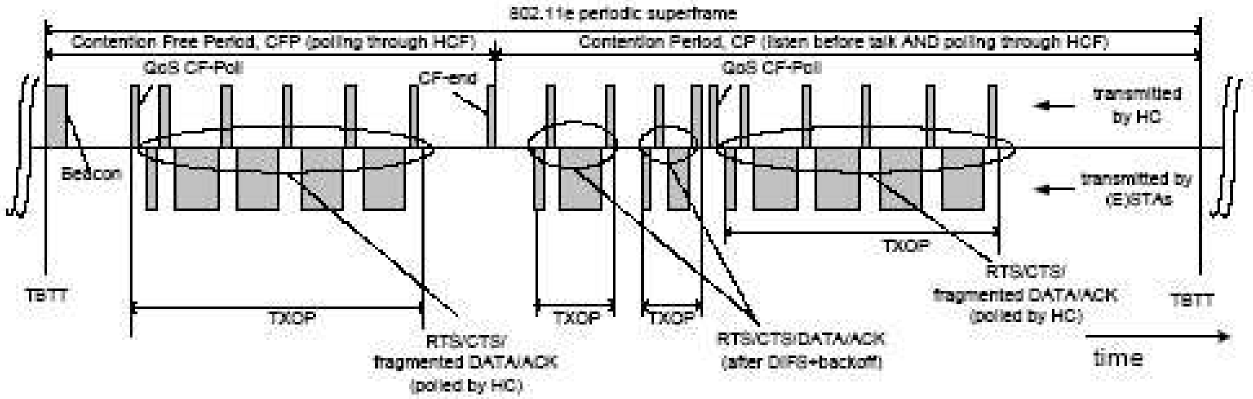

Figure 7: 802.11e superframe: Polled TXOPs can lie both in CP and CFP, from [1]

get doubled. In EDCF the new CW size depends upon the Persistence Factor(PF[TC]). This helps in preventing new collisions between different Traffic Categories..

$$newCW[TC] >= ((oldCW[TC]+1)*PF[TC])-1 \quad (1)$$

The normal doubling of CW is equivalent to PF = 2. CW size never exceed the parameter $CW_{max}[TC]$ which is the maximum possible size of CW.
To implement priority within a station, a station may implement up to eight transmission queues or priority levels. Thus, a station can be realized as number of virtual stations with QoS parameters to determine their priority. A virtual collision can occur if counters of two or more parallel TCs in a single station reach zero at same time. There is a scheduler inside a station to prevent such collisions. Scheduler grants TXOP to the TC with the highest priority.

Thus, the priotized channel access is realized with the Qos parameters per TC such as AIFS[TC], $CW_{min}[TC]$, $CW_{max}[TC]$, PF[TC] etc.

5.2 Hybrid Coordination Function

Hybrid Coordination Function is very similar to PCF. Similar to Point Coordinator in PCF mode, in HCF we have Hybrid Coordinator(HC). HC is an enhanced station which may optionally work as the centralized cooridinator for all other enhanced stations within the same Basic Service Set(BSS). With 802.11e, there may still be two phases within the superframes, CP and the CFP, which alternate over time. The EDCF is used in CP only, whereas the HCF is used in both CP and CFP, making the new coordination function as hybrid. Recall that in PCF, we used DCF during CP and only PCF during CFP.

The HC, being the priority coordinator may allocate TXOP to itself whenever it wamts, after sensing channel to be idle for PIFS. To assure that HC has higher priority PIFS is shorter than AIFS. During CP, there are two ways a TXOP can begin.

1. Under the EDCF rules i.e. after waiting AIFS plus backoff time.
2. On receiving special poll frame, the QoS CF-poll from the HC.

HC can send the QoS CF-poll after a PIFS idle period without any backoff. Thus, HC can issue polled TXOPs in the CP using its prioritized medium access.
During the CFP, HC uses QoS CF-poll frames to specify the starting time and the maximum duration of the TXOP. During CFP, only HC grants the TXOPs by sending the poll frames. Stations do not attempt to get medium access on their own during CFP. The CFP ends by the CF-end frame from the HC or by the time announced in the beacon frame. Figure 7 gives an example for a superframe.

6 Traffic Categories

We have been talking about Traffic Categories for so long. Now let us look at some of the mechanisms that can be implemented at the Access Points for applying traffic classification to particular traffic types.

6.1 Appliance-based Prioritization

If a client identifies itself as a particular appliance, then it can be prioritized accordingly. For eg. if a appliance identifies itself as a Voice over IP(VoIP) appliance, it can be given provided traffic with interactive voice classification.

6.2 VLAN-Based Prioritization

Default priority for a Virtual LAN can be set. Thus, this priority will be applied to all traffic, unless there is some filter setting.

6.3 Class of Service(CoS) value-based Prioritizaion

Traffic that comes to the access point can already be classified by using Layer 2 ethernet CoS settings. This classification can be mapped to EDCF and can be given appropriate priority.

6.4 Types of Service(ToS) and DSCP value-based Prioritization

Layer 2 media often changes as a packet travels from source to destination. Hence a more general approach is to classify at layer 3. The second byte in a packet here is Type of Service(ToS). ToS is intended for specifying Quality of Service on a per packet basis. The first six bits of ToS are known as Differentiated Service Code Points(DSCP). A mapping can be definced from DSCP to CoS. For eg. DSCP value 48 can be mapped to Interactive Video.

7 Summary and Conclusion

The support of a common system for both data and voice traffic would be simpler and less expensive than two separate entities. In this report, we presented a comprehensive overview of QoS supporting protocol 802.11e compared to legacy 802.11. The upcoming standard 802.11e would provide an efficient mean for QoS support. Still, these protocols are not robust enough for many enterprises as current offerings do not enable the kind of reliability that we need to have many times in a voice network.

8 Acknowledgement

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References

[1] S. Mangold, S. Choi, P. May, O. Klein, G. Hiertz, and L. Stibor. Ieee 802.11e wireless lan for quality of service (invited paper). volume 1, pages 32–39, Florence, Italy, feb 2002.

[2] A. Koepsel, J.-P. Ebert, and A. Wolisz. A performance comparison of point and distributed coordination function of an ieee 802.11 wlan in the presence of real-time requirements. In *Proc. of 7th Intl. Workshop on Mobile Multimedia Communications (MoMuC2000)*, Tokio,Japan, October 2000.

[3] Cisco Systems. Wireless quality-of-service deployment guide. Technical report, Cisco, 2003.

[4] Gregori. E. Cali. F, Conti. M. Ieee 802.11 wireless lan: capacity analysis and protocol enhancement. In *INFOCOM '98. Seventeenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, 1998.

[5] Tanenbaum A. S. *Computer Networks.* Pearson Education, 2003.