DCF Improvement for Satisfactory Throughput of 802.11 WLAN

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***Abstract*—As demand for deployment and usage is increased in WLAN environment, achieving satisfactory throughput is one of the challenging issues. Initially as WLAN environment is data centric, the best effort delivery based protocol serve the purpose up to certain extent. With multimedia traffic protocol fails to deliver required traffic. The requirement of satisfactory network performance is delivery of QoS. The QoS demand controlled jitter and delay, dedicated bandwidth etc. This triggers various approaches of modifying existing protocol to achieve acceptable throughput to satisfy user requirement. In this paper we will discuss how WLAN MAC protocol responds to network traffic and the shortcomings of existing protocol while responding it.**

Keywords- 802.11 MAC layer, DCF, DCF limitation

I. INTRODUCTION

Existing WLAN applications are mainly data centric; there is growing demand for real time services over WLAN. Now days it is nevertheless, to use WLAN for multimedia servers allocated in a wired network. WLAN is no-blocking system: new users entering into the system try to access the shared medium for transmitting and receiving data. Consequently, throughput decreases with increasing number of users. This is particularly true for 802.11 MAC based on DCF access method.

The 802.11 MAC protocol was carefully designed for the wireless LAN environment and many of the underlying assumptions may not hold in the new environments. Media Access Control (MAC) controls and manages the access and packet transmission through the shared channel in a distributed manner, with minimum possible overhead involved In 802.11, Basic Service Set (BSS) can be classified as Independent mode and Infrastructure mode. In independent mode communication take place in ad hoc manner and in infrastructure mode communication take place through access point. The IEEE 802.11 defines a basic service set (BSS) as the number of stations controlled by a single coordination function. The MAC layer of 802.11 works on logical function, these logical functions are also known as coordination functions. The 802.11 standard defines two forms of medium access, distributed coordination function (DCF) and point coordination function (PCF).Point coordination function is centralized protocol and optional. In PCF, as it is centralized, no collision will occur. The pooling mechanism is used by PCF for gaining the access of channel. The PCF has not been studied as much as the DCF. DCF is mandatory and based on the CSMA/CA (carrier sense multiple access with collision avoidance) protocol. These MAC layer protocols of wireless LAN can be classified as follows:

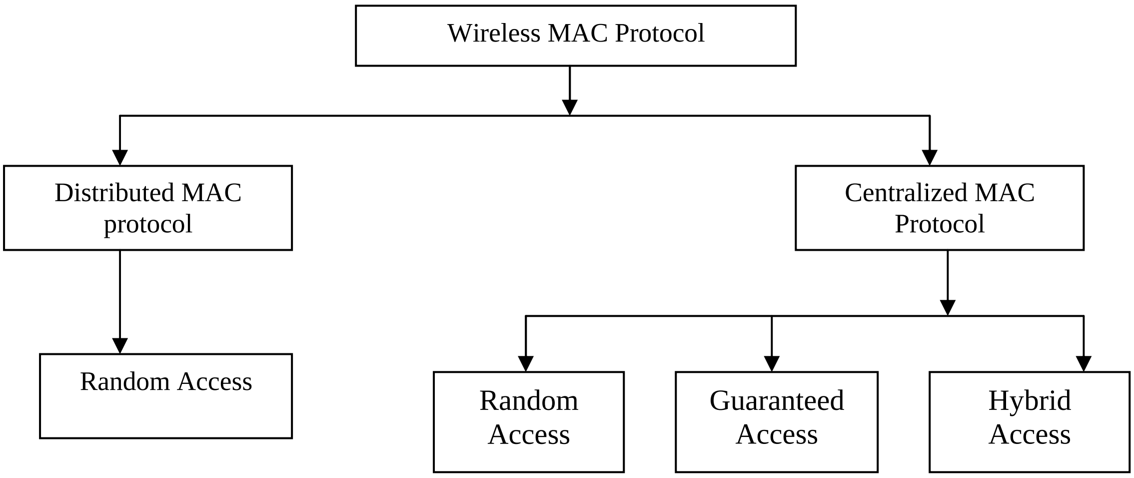

Figure 1. Wireless MAC Protocol

Distributed Coordinated Function protocol is followed by many industrial standards. It has been analytically and demonstrated by simulations that the maximum throughput that a user can expect in a WLAN with DCF is significantly slower than the nominal bit rate due to the CSMA/CA protocol characteristics and the amount of overhead bits. Achieving QoS with this standard is difficult. In this case throughput can be used as measuring parameter for achieving QoS with DCF mechanism. Throughput is the average rate at which the data travels between two users and is usually measured in kbps or Mbps. It should also be noted that the throughput is measured at the Application level to reflect as accurately as possible the performance that is actually experienced by the end user. This, however, implies that throughput does depend on the underlying transmission protocol (TCP or UDP) and data type being sent (i.e., HTTP, FTP, VoIP, etc). Data bandwidth is the maximum theoretical throughput or data rate at which data can be transmitted over the network. In a WLAN network the actual throughput will depend on, the radio transmission environment, the characteristics of the information to be transmitted (i.e. packet size), and number of transmitters active.

DCF access mechanism makes system performance sensitive to number of stations and their traffic profiles.

II. DCF MECHANISM

Distributed coordination function (DCF), a mechanism of IEEE 802.11 MAC layer is used to share medium between multiple stations. Before transmitting frames, a station must first gain access to the medium, which is a radio channel that stations share. To better understand the performance of WLANs, a critical challenge is how to analyze IEEE 802.11 DCF. In 802.11 standards, distributed coordination function (DCF) is defined for asynchronous data transfer. An asynchronous data transmission involves a mechanism called a queue. Distributed coordinated function works with First In First Out transmission queue.

The DCF describes two access techniques for packet transmission: the basic access mechanism and the RTS/CTS mechanism. The basic mechanism is a random access scheme, based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. The carrier sense in CSMA means that the devices will attempt to sense whether the physical medium is available before communicating. The basic scheme uses DATA/ACK two-way handshaking to determine whether the DATA packet is successfully transmitted in the channel; while the RTS/CTS mechanism tries to reserve the channel by smaller control packets (RTS and CTS) before the DATA transmission. RTS/CTS access mechanism addresses hidden node problem.

In basic access mechanism, before transmitting, each station should sense whether channel is idle. If the channel is busy then other channel will set backoff time to avoid collision. Distributed Coordination Function (DCF) algorithm is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) technique. This technique enables multiple users to share the same physical medium, avoiding collisions and consequently signal degradation.

To avoid the hidden terminal problem, the CSMA/CA protocols are extended with a virtual carrier sensing mechanism, named Request To Send (RTS)/Clear To Send (CTS). Request-to-send and Clear-to-Send

(RTS/CTS) handshaking scheme leading to the Multiple Access Collision Avoidance (MACA) protocol proposed by Karn [2]. RTS/CTS access mechanism handshakes before transmission of data packet. Station operating in RTS/CTS mode "reserves" the channel by sending a special Request-To-Send short frame. The destination station acknowledges the receipt of an RTS frame by sending back a Clear-To-Send frame, after which normal packet transmission and ACK response occurs Since collision may occur only on the RTS frame, and it is detected by the lack of CTS response.

III. DCF LIMITATION AND COUNTERMEASURES

To handle multimedia traffic effectively the QoS metric has to consider. The important QoS metrics for multimedia applications are delay, jitter, and throughput. End-to-end delay is the time between the arrival of a packet and its successful delivery to the receiver. Jitter is the variation of delay and is an important metric for multimedia applications. To support QoS in WLAN there has to be some mechanisms to control network loads under a threshold so that system can provide satisfied performance.

Satisfying this requirement of QoS for delivering multimedia traffic imposes challenges due to limitation of DCF. In DCF, all the stations share the same queue in a round robin manner without any priority. Packets go to the queue and operate in a FIFO (first in first out) mechanism; no scheduling of packets is done.

QoS mechanisms associated with DCF is can be divided into following categories as shown in Figure 2.

Classification: there is no classification mechanism or service differentiation provided.

1. Channel access: contention-based media access control mechanism.
2. Packet scheduling: packet scheduler uses FIFO mechanism.

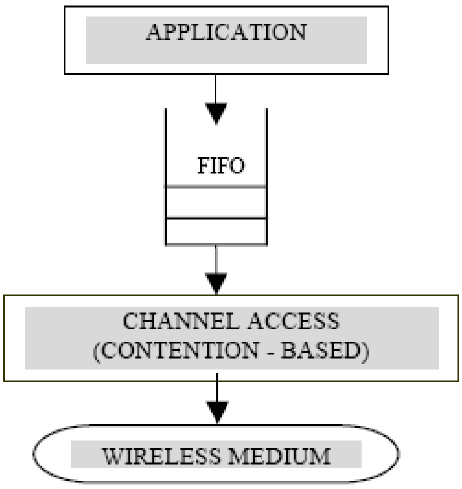

Figure 2 DCF Limitation

Even though DCF is a simple and effective mechanism, DCF can neither support QoS nor guarantee to meet the multimedia applications requirements. That is to say, DCF does not comprise the differentiation mechanisms guaranteeing bandwidth, packet delay, and packet loss-rate and/or jitter bounds for high priority stations or multimedia flows. Typically, time-bounded services such as Voice IP, audio and video conference require specified bandwidth, delay and jitter, but can tolerate some losses. However, in DCF mode, all the stations in one BSS or all the flows in one station compete for the resources and channel with the same priorities. There is no differentiation mechanism to guarantee bandwidth, packet delay and jitter for high-priority stations or multimedia flows. Throughput degradation and high delay are caused by the increasing time used for channel access contention. The key is that in DCF, all the stations compete for the medium with the same priorities. Unless admission control is used, there is no way to guarantee the QoS requirements for high-priority traffic in DCF. DCF has been basically designed for providing a best-effort service. Legacy DCF MAC does not support the concept of differentiating frames with different user priorities. The DCF is supposed to provide a medium access with equal probabilities to all stations contending for the channel access in a distributed manner. Nevertheless, equal access probabilities are not desirable among stations with different QoS requirements. The QoS-aware MAC should be able to treat packets with different QoS requirements differently.

The above point of DCF can be summarized as:

- DCF can only support best effort services, not any QOS guarantees.
- In DCF, all the stations in one Basic Service Set (BSS) or all the flows in one station compete for the resources and channel with the same priorities.
- There is no differentiation mechanism to guarantee bandwidth, packet delay and jitter for high priority stations or multimedia flows.
- Throughput degradation and high delay are caused by the increasing time used for channel access contention.

The unfairness of TCP traffic can be addressed extensively in literature to achieve QoS in WLAN. This issue arises due to channel access mechanism of DCF. DCF mechanism gives equal opportunity to each station for competing for access of channel. The station with low transmission rate occupies channel for longer period than higher rate stations. The access point also one of the stations for competition for achieving medium control. But it has to address with the uplink and downlink traffic. When access point associate both uplink and downlink traffic, uplink traffic occupies channel more than downlink traffic. This is called unfairness issue between uplink and downlink traffic and with TCP mechanism this issue arises more. The TCP mechanism involves acknowledgement packet. As access point occupied with uplink traffic, downlink traffic get congested and buffer overflow occurs at access point. As TCP data packets drops, sender retransmits these packets and reduce contention window size, which reduces sending rate. This results in longer time of occupying channel by sending station. This makes unfairness issue more worst. The issue of unfairness in TCP traffic is addressed extensively in WLAN literature. One of the directions of research in reducing unfairness issue is by frame control. Author Kaschibuchi et.al. proposes channel occupancy time based TCP rate control to improve transmission efficiency in multirate WLAN environment[3].Author proposed scheme in which each station estimates for how long it can use medium. Station can estimate time by monitoring at MAC layer. This time is used by station to calculate maximum throughput at TCP layer. At TCP layer, TCP sender calculates appropriate window size and accordingly adjusts maximum window size. This computation can be made by updating firmware/kernel in access point and station.

Due to unfairness issue while carrying TCP enabled traffic in WLAN, it is necessary to estimate capacity of WLAN to carry common internet applications such as file transfer or packet voice telephony. Author George Kuriakose et.al. provide analytical for such estimation by considering three different scenario [4]. This capacity estimation gives number of TCP controlled file transfers can be done at a time to maintain minimum throughput per station of at least 25kbps or number of packet telephone calls can be set up with minimum packet delay. In other words, above analytical work provides guidelines for different type of traffic capacity estimation WLAN infrastructure mode with stochastic model. The first scenario consider file transfer type TCP application, in which client transfer huge data file from server to another client through access point. The second scenario considers VoIP call in WLAN in which achieving QoS is major issue by maintaing acceptable throughput. Third scenario explores VoIP calls originated from different clients from different codec. The purpose of exploring such scenarios is to estimate admissible region for different types of traffic. For each scenario embedded markov chain model is analyzed. The Markov regenerative framework is developed to derive performance measures such as acceptable throughput and collision probability. The accuracy of model is asserted by other parameters such as collision probability and attempt rate. Assumption made for analysis is that access point buffer is infinite and there is no packet drop. The model analyze access point is bottleneck for supporting more number of VoIP calls. Despite of simple modeling, suggested model proves efficient for estimating capacity region with satisfactory performance.

Author Albert Banchs et.al proposes scheme based on extension relies on the Distributed Coordination Function (DCF) with a modified algorithm for the computation of the Contention Window (CW) [5].Paper proposes an Assured Rate Service Extension for the MAC layer of the IEEE 802.11 standard (ARME: Assured Rate MAC Extension), in line with the Assured Rate PDB proposed for DiffServ. This Assured Rate Service guarantees a specific throughput to its user. A typical user of this service could be the CEO of a company requiring a high speed access to Internet independent of the level of congestion of the company's Wireless LAN. Also like DiffServ, the ARME architecture provides a soft kind of QoS, i.e. statistical QoS guarantees are given to traffic aggregates, but an individual packet does not receive any kind of guarantee. ARME distinguish two types of service: the Assured Rate Service and Best Effort. An Assured Rate station in ARME is a station that has contracted a service with a certain assured rate, while a Best Effort station has not contracted any rate. In ARME, the Assured Rate Service is supported by the DCF function of the current standard with minor changes in the computation of the CW in order to give to each station the expected throughput according to the service contracted by the station. Thus, both the Assured Rate station and the Best Effort access the channel with the DCF mode but with different CWs.

The approach chosen for the calculation of the CW in ARME is a dynamic one: each station monitors the bandwidth experienced and modifies its CW in order to achieve the desired throughput. ARME provides Assured Rate terminals with its guaranteed throughput in normal circumstances, while the leftover bandwidth is shared equally between Best Effort and Assured Rate.

The DCF of WLAN usually operates with multi-rate adaptation such as ARF, the objective of which is to select a suitable Transmission Mode (TM) to maximize the data rate while maintaining a prescribed Frame Error Rate (FER). However, the ARF with the DCF may not be able to tell collision from channel noise, resulting in throughput degradation in the network.

Author Jun Zhao et.al to analyze the MAC with different QoS, propose a class-based analytical framework to model the IEEE 802.11 MAC with differentiated access parameters [6]. The key assumption is to approximate the DCF as p-persistent CSMA/CA MAC. Consider two stations running on a CSMA/CA protocol. One station samples the backoff counter from a geometric distribution with parameter p and the other station samples from a uniform distribution [0, E [CW]], where E [CW] is the expectation of CW. The two stations have the same backoff counter if

$$p = 2/1 + E[CW]$$

Suppose there are M classes and each class has $N^{(l)}$ (l =1,2,……..M) active stations. The initial contention window of class i is $CW^{(l)}$. The maximum backoff stage is m. The probability that a station in class l will sense a busy channel before transmission is denoted as $p^{(l)}_{busy}$. The expectation of contention window of class l is $CW^{(l)}_{exp}$.

The expected contention window $CW^{(l)}_{exp}$ is given by

$$CW^{(l)}_{exp} = CW^{(l)}/(1 + p^{(l)}_{busy} \sum_{i=0}^{m-1} (2+ p^{(l)}_{busy})^i)$$

In a class-based WLAN, a station of class l may encounter several types of events before it can successfully transmit a packet. The average sharing of bandwidth of a station in class l is given by

$$BW^{(l)}_{persta} = msg^{(l)}/N^{(l)}T^{(l)}_r$$

The total goodput of the system is derived as

$$G = \sum_{l=1}^{m} BW^{(l)}_{persta} N^{(l)}$$

To support QoS traffic classes in a WLAN, the MAC layer should satisfy the bandwidth requirement of each traffic class in addition to maximize system goodput. Given a system configuration, the MAC should choose the optimal access parameters (CW and QIFS) to maximize the goodput while maintaining bandwidth constraints of each class. The problem is formulated as a constrained optimization problem

$$\begin{gathered} \text{Maximize } G \\ \text{s.t } BW^{(l)}_{persta} \geq BW^{(l)}_{min} \\ CW^{(l)} \geq CW_{min} \\ QIFS^{(l)} \geq DIFS \\ l = 1, 2, 3\ldots\ldots\ldots\ldots M \end{gathered}$$

IV. ROADMAP OF MAC PROTOCOL IMPROVEMENT

In this paper we have analyzed that mandatory protocol of WLAN which is DCF suffers from limitation such as performance anomaly, TCP unfairness. These limitations can be try to overcome by 802.11e standards which implements EDCA protocol. To support multimedia application 802.11e introduces hybrid coordination function. HCF includes two medium access mechanisms: contention based channel access and controlled channel access (includes polling). Contention-based channel access is referred to as enhanced distributed channel access (EDCA), and controlled channel access is referred as HCF controlled channel access (HCCA).

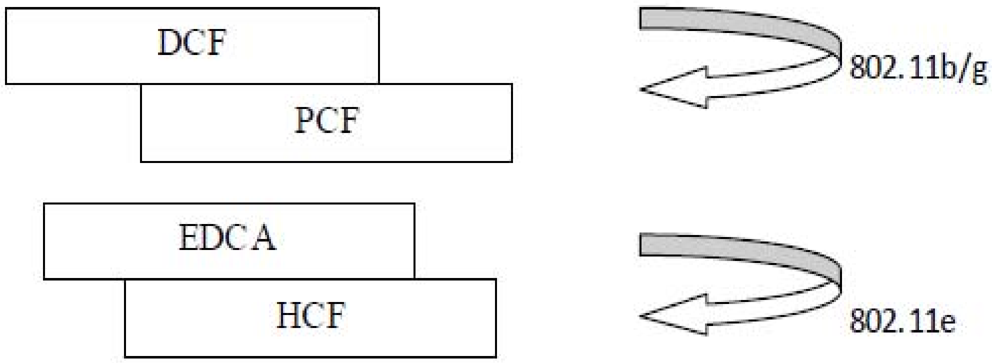

Figure 2. IEEE 802.11 WLAN Protocol

EDCF in 802.11e is the basis for HCF. EDCF is used in the Contention Period only.
Hybrid Coordination Function includes feature for both distributed access when talking of DCF and PCF centrally controlled access of medium, this combination is to achieve a level of QoS by using the features of both of them it makes this function Hybrid. We can say this is the Enhancement of both DCF and PCF.
1. Distributed contention based medium access i.e. Enhanced Distributed Channel Access (EDCA).
2. Controlled centrally contention-free medium access i.e. HCF controlled Channel Access (HCCA).
The 802.11e protocol improves DCF limitation by introduction of admission policy. Admission control is an important tool to control the number of flows in network to maintain the QoS experienced by end users. With the increasing demand on high priority applications like voice over IP and video conference in WLAN, it is necessary to make sure the QoS of these applications do not degrade severely when the network is heavily loaded. Up to now, most of the researches on QoS in WLAN concentrate on resource allocation. Not many researchers have been focused on admission control especially for IEEE 802.11e WLAN. Sachin and Kappes [7] proposed an admission control method for Voice over IP traffic in IEEE 802.11 WLAN. However, the method was only tested in ordinary IEEE 802.11 DCF access mechanism.

CONCLUSION

As discussed above deploying WLAN with DCF protocol does not serve the purpose to full extent. The reason behind this is DCF is designed by keeping data centric traffic in mind, the challenge to achieve multimedia traffic with QoS requirement is still to meet. To deliver QoS requirement 802.11e protocol is designed with the service differentiation and priority based approach. But as due to simplicity of implement the DCF is choice of most of the vendors. Thus network administrator has to select particular protocol to meet specific requirement of network. But having change in protocol to achieve particular requirement is not feasible solution for dynamically changing network environment. Keeping the existing scenario of respective network with respective protocol, there should be common policies define which meet requirement of network. These policies should be unlike policies defined in 802.11e. Rather than being protocol dependent, policies should be network requirement dependent. The future research direction should be in reference to dynamic changing network environment. The network should be make decision either by cognitive approach or by hierarchical model which define polices of network according to various criteria.

REFERENCES

[1] IEEE 802.11 standard for Wireless Local Area Networks, http:// standards.ieee.org/getieee802/802.11.html

[2] Phil Karn, " MACA - A New Channel Access Method for Packet Radio"

[3] Kenichi Kashibuchi, Abbas Jamalipour, Nei Kato, "Channel Occupancy Time Based TCP Rate Control for Improving Fairness in IEEE 802.11 DCF", IEEE 2010.

[4] George Kuriakose, Sri Harsha, Anurag Kumar and Vinod Sharma, "Analytical Models for Capacity Estimation of IEEE 802.11 WLANs using DCF for Internet Applications".

[5] Albert Banchs, Xavier P´erez, "Providing Throughput Guarantees in IEEE 802.11Wireless LAN" WCNC 2002, vol. 1, pp. 130-138, March 2002.

[6] Jun Zhaoy , Qian Zhang, Zihua Guo and Wenwu Zhu, "Throughput and QoS Optimization in IEEE 802.11 WLAN", Microsoft Research.

[7] Dongyan Chen, Sachin Garg, Martin Kappes and Kishor S. Trivedi, "Supporting VoIP Traffic in IEEE 802.11 WLAN with Enhanced Medium Access Control (MAC) for Quality of Service"

[8] Benny Bing, "Emerging Technologies in Wireless LANs: Theory, Design and Deployment".

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