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A Modified MAC Behaviour for Multimedia Traffic in Wireless LAN for QoS Provisioning

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Abstract

IEEE 802.11 Wireless LAN (WLAN) developed as a simple and cost-effective wireless technology for best effort services, IEEE 802.11 has gained popularity at an unprecedented rate. However, it lacks of the capability to support Quality of Services (QoS) such as multimedia and real-time traffic properly. This paper presents a simple approach to enhance the multimedia real-time performance over the 802.11 WLAN by implementing a Quality of Service Manager (QoSM) for differentiating services with two queues on top of the 802.11 Medium Access Control (MAC) controller. By simulation approach the proposed scheme is remarkably effective for the multimedia real-time service (which improves in delay and throughput approximately 24 –25%) in the infrastructure-based WLAN in the coexistence with the non-real-time traffic.

Keywords- IEEE 802.11, WLAN, QoS, MAC, QoSM, and QEM.

1. Introduction

In the recent years, IEEE 802.11 WLAN has gained the prevailing position in the market for the (indoor) broadband wireless access networking. The IEEE 802.11 defines the functionality of medium access control (MAC) layer and physical (PHY) layer specifications for WLAN [1]. The mandatory part of the MAC is the distributed coordinated function (DCF), which is based on Carrier Sense Multiple Access (CSMA/CA) [2][9]. Most of the 802.11 devices implement the DCF only because of the contention-based channel access nature, which supports best-effort service without guaranteeing any QoS and having no service differentiation [1][7][8]. WLANs has limited to the non-real-time best-effort services. A wireless multimedia LAN approach has described in [4] with DCF and shortened contention window for QoS provisioning. 802.11 devices are not capable to support the RT services, which are delay-sensitive while tolerable some loss up to loss rate of 1% ~ 3%. The emerging 802.11e MAC, which is an amendment of the existing 802.11 MAC, provide QoS for best effort, voice and video with different queues [3][10]. A similar architecture for Wireless Multimedia LAN by using DCF with shortened contention window has also described in [5] and a cross layer framework for QoS support is described in [9].

In this paper we consider a software upgrade-based approach to provide a limited QoS for real-time multimedia service enhancement over the 802.11 WLAN. The prime objective of the architecture is to provide stations within WLAN with an ability to watch live programs, and on-demand video services. In this scheme it implements a QoSM with Q_q and BE_q on top of the 802.11 MAC controller. Basically, the Q_p and BE_p packets are classified and enqueued into one of the two queues. Then after a strict priority policy is used to forward the packets from two queues in order to give a priority to quality (real-time multimedia) packets from Q_q, the BE_q queue is never served as long as the Q_q is non-empty.

The rest of the paper is organized as follows. In section 2, IEEE 802.11 MAC is briefly reviewed. The proposed QoS Management Strategy is presented in Section 3. Section 4 discusses the Mathematical Analysis of the model. The performance of the conventional MAC DCF and proposed QoSM with MAC DCF has been studied by simulation using ns2 is discussed in Section 5., we conclude in Section 6 by discussing the future work and references are added in section 7.

2. IEEE 802.11 MAC

The IEEE 802.11 legacy MAC defines two coordination functions, namely, the mandatory distributed coordination function (DCF) based on CSMA/CA and the optional point coordination function (PCF) based on polling mechanism [1]. Most of today's 802.11 devices operate in the DCF mode. Here a briefly overview how the distributed coordinated coordination function works has described.

WLAN MAC [1] [2] works with a single queue first-in-first-out (FIFO) transmission mechanism and is shared by all the traffics. The CSMA/CA of DCF works as follows: when a packet arrives at the front of transmission queue, if the channel is found idle for an interval of time longer than Distributed Interframe Space (DIFS), the source station can transmit the packet immediately, mean while other stations defer their transmission while adjusting their network allocation vector (NAVs) and the backoff process starts. In this process, the station computes a random interval, called backoff-timer, selected from the contention window (CW): *backoff-timer= rand [0,CW]* Slot-Time*, where $CW_{min}<CW<CW_{max}$. The backoff-timer is decreased only when the medium is idle. If the channel is busy, the MAC

waits until the medium becomes idle, then defers for an extra time interval, called the DIFS. If the channel stays idle during the DIFS deference, the MAC then starts the backoff process by selecting a random backoff counter. For each idle slot time interval, the backoff counter is decremented. When the counter reaches zero, the packet is transmitted. The mechanism of DCF channel access is illustrated in Fig. 1.

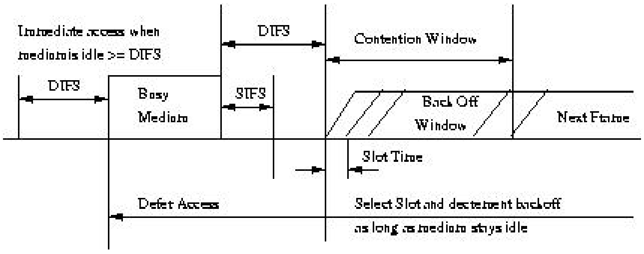

Figure 1. 802.11 DCF access scheme

If the channel becomes busy during a backoff process, the backoff is suspended. When the channel becomes idle again, and stays idle for an extra DIFS time interval, the backoff process resumes with the suspended backoff counter value. For each successful reception of a packet, the receiving station immediately acknowledges by sending an acknowledgement (ACK) packet. The ACK packet is transmitted after a short inter frame space (SIFS), which is shorter than the DIFS. If an ACK packet is not received after the data transmission, the packet is retransmitted after another random backoff [2]. The CW size is initially assigned CW_{min}, and increases when a transmission fails. MAC parameters including, DIFS, SIFS, Slot Time, CW_{min}, and CW_{max} are dependent on the underlying physical layer (PHY). Table I shows the parametric values for the 802.11b [2]. The 802.11b PHY supports four transmission rates, namely, 1, 2, 5.5, and 11 Mbps. Here the 802.11b PHY is taken even if the proposed QoSM scheme should work with any PHY [11].

3. Quality Of Service Management Strategy

In this approach a Quality of Service Manager (QoSM) is implemented inside the access point (AP). The QoSM differentiate the flows and put them in the appropriate queue. This is implemented above the 802.11 MAC controller, so that the packet scheduling can be performed above the MAC without modifying it. The Fig. 2 shows the structure of QoSM to support the quality by differentiating the flows come to it. There is no service differentiation in the MAC [8][10], it uses a single queue to transmit packets. When ever a packet arrives at AP is processed and sends it to the appropriate queue by the help of queue assignment (QA) and forwarded to the MAC controller for transmission with strict priority policy.

QoSM differentiate between the real-time multimedia packet and the general (FTP) packet and put it into the two FIFO queues, called Quality queue (Q_q) and Best-Effort queue (BE_q). Here we divide the stations address between two groups i.e. the stations having the range of address in first group can capable to send real time data and other range of address can capable of send the FTP data but can able to access the stored video in the video server (which is known as Video on Demand, VoD). The current IP datagrams do not carry any information about corresponding applications or QoS requirements, and hence we use the source address and packet type to differentiate a multimedia packet and data packet.

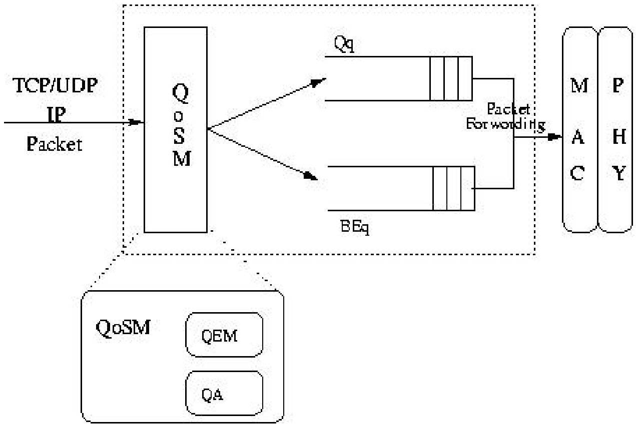

Figure 2. QoS Management Scheme

As shown in the Fig. 2 QoSM contains two modules, Quality Evaluation Module (QEM) and Queue Assignment (QA). In QEM, it differentiates the real-time multimedia flow and general TCP flow and assigns packets to the corresponding Q_q or BE_q both are FIFO queue. The following algorithm describes basic functionality.

P_i:	i^{th} packet in transmission
P_t:	Packet Type
Q_p:	Quality Packet
BE_p:	Best Effort Packet

QoSM (Receive P_i)
1. P_t =QEM (P_i)
2. If ($P_{t\,=}\ Q_p$)
3. If (Q_q = full)
4. Then drop P_i
5. Else QA (P_i, Q_q)
6. Else if ($P_{t\,=}\ BE_p$)
7. If (BE_q = full)
8. Then drop P_i
9. Else QA (P_i, BE_q)

QEM (Differentiating Packet Type)
1. Process P_i to find out the source address
2. If (source address within the classified range of first group)
3. Then return (Q_p)
4. Else
5. Return (BE_p)

In accordance of the procedure described above, whenever QoSM receives a packet P_i it calls the QEM. The QEM contain the address ranges of the stations, which is used to classify the packets as described in the procedure, i.e. if the address comes under the first group then it returns a Q_p otherwise a BE_p. After getting the packet type from QEM then it do the queue assignment by the help of QA module if the queue is not full for both the type of packets. Packet forwarding is done in a strict priority policy i.e. whenever there is packet in the Q_q it will not transfer the packets from BE_q.

As shown in the Fig. 3 the component interaction is as per the arrow marked in the diagram. Whenever QoSM receives a packet it calls the QEM as shown to find out the quality of the packet and after it calls the Queue assignment module to assign the packet to the proper queue. Then after the forwarding of packet is taken place. Here the transmission of the packet is done as per the legacy MAC with contention based channel access [1][2][8][11].

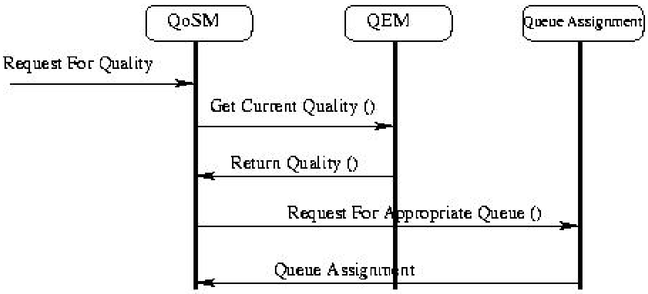

Figure 3. Component diagram of QoSM

4. Mathematical Analysis

As shown in Fig. 2 it uses QoSM based on Queue model with two distinguished queue Q_q and BE_q. As it uses strict priority policy i.e. it don't serve the BE packet as long as quality packets are available. Priority packets do not have to wait, known as preemptive. A system and user centric queueing model for IEEE 802.11 WLAN is described in [4]. The queueing delay of the Q_q can be calculated by analyzing the behavior of the model. So the process can be modeled with M/M/1/N. Where the queue length is N and are drop tailed. Packets arrive with rate λ packets per second for states i=0,1,2…N-1, so inter-arrival time $1/\lambda$ second per packet. And the packets get served with a rate of μ packets per second for states i=1,2,3,…N. If N packets in the queueing system, then the requested packet is lost.

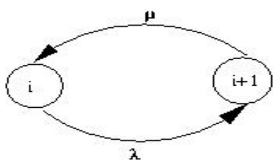

Figure 4. State Transition Diagram of Finite capacity (N) Queue

From the Fig. 4 when the system is in i^{th} state with an arrival then it goes to $i+1^{th}$ state and after serving a packet goes from $i+1^{th}$ to i^{th}, where $0 \le i \le N$. So the states of the system are i= 0, 1, 2, … N) and state probability of the process are: p= [$p_0, p_1, p_2, \ldots p_n$] and $\Sigma p_i=1$. Between each pair of adjacent states, the flow of probability flux from left to right with the flow probability flux from right to left yields the balance equations:

$\lambda p_0=\mu p_1,\ \lambda p_1=\mu p_2,\ \lambda p_2=\mu p_3 \ldots\ldots \lambda p_{n-1}=\mu p_n$

$\Rightarrow p_1 =(\lambda/\mu)p_0,\ p_2 =(\lambda/\mu)p_1 \ldots\ldots p_n =(\lambda/\mu)p_{n-1}$

By substituting these recursions into each other yields to

$$p_n = \left(\frac{\lambda}{\mu}\right)^n p_o, 0 \le n \le N \quad (1)$$

To calculate p_0, from $\sum_{n=0}^{N} p_n = 1$

$$p_0 = 1 \Big/ \sum_{n=0}^{N}\left(\frac{\lambda}{\mu}\right)^n$$

$$\Rightarrow p_0 = \frac{1-\lambda/\mu}{1-\left(\lambda/\mu\right)^{n+1}} \quad (2)$$

Putting the value of Eq. (2) in Eq (1) yields

$$p_n = \frac{1-\lambda/\mu}{1-\left(\lambda/\mu\right)^{n+1}}\left(\frac{\lambda}{\mu}\right)^n, 0 \le n \le N \quad (3)$$

4.1 Performance Measure in the Queueing System

Mean Throughput $\overline{Y} = \sum_{n=1}^{N} \mu p_n = N\mu$ (4)

Where $\sum_{n=1}^{N} p_n = 1$

When n=0, the queueing system is empty and there is no contribution to throughput. Mean throughput Eq (4) is a weighted average of service rates where the state probabilities serve as weights. Mean number of packets in the queueing system is

$$\overline{n} = \sum_{n=1}^{N} n p_n \quad (5)$$

By applying the Little's Law to write the expression for mean time delay in queueing:

$$\overline{n} = \lambda\overline{\tau}$$

$$\Rightarrow \tau = \frac{\overline{n}}{\overline{Y}}$$

$$\Rightarrow \tau = \frac{\sum_{n=1}^{N} n p_n}{N\mu} \quad (6)$$

4.2 Performance Measure of the System

T_{phy}	Transmission time of physical layer
T_{H_data}	Transmission time of MAC overhead
T_{data}	Transmission time of payload (actual data)
L_{data}	Payload size in byte
R_{data}	Data rate
P_d	Propagation delay
T_{DISF}	DIFS time
T_{SIFS}	SIFS time

Propagation delay P_d = Time taken transmit between source to AP and AP to destination + Queueing delay τ. The Queueing delay τ is taken from the Eq. (6). Throughput and delay formulation can be done as described in Eq. (10) and Eq. (11). But in a noisy channel, the throughput is expected to be less than the maximum throughput and the delay is expected to be larger than the minimum delay. A transmission cycle of DCF consists of DIFS deferral, backoff, data transmission, SIFS deferral and ACK transmission. Average Backoff Time [12]

$$BT_{avg} = \frac{CW_{\min} T_{slot}}{2} \quad (7)$$

Data transmission delay

$$T_{D\_data} = T_{phy} + T_{H\_data} + T_{data} \quad (8)$$

Acknowledge transmission delay

$$T_{D\_ack} = T_{phy} + T_{ack} \quad (9)$$

So the maximum throughput *(T_{MAX})* of the system is given as

$$T_{MAX} = \frac{L_{data} \times 8}{T_{D\_data} + T_{D\_ack} + 2P_d + T_{DIFS} + T_{SIFS} + BT_{avg}} \quad (10)$$

where $L_{data} \times 8$, as it is in byte.

Packet delay is the time elapsed between the transmission of a packet and its successful reception. The Minimum Delay *(D_{MIN})* of the system is given as:

$$D_{MIN} = T_{D\_data} + P_d + T_{DIFS} + BT_{avg} \quad (11)$$

The performance of D_{MIN} and T_{MAX} has been studied with the help of ns2 in next section.

5. Simulation Analysis

This section contains the performance evaluation of the legacy MAC and QoSM a modified MAC behavior using ns-2 simulator [6] to show the utility of QoSM scheme for real-time multimedia application over an infrastructure based WLAN environment. The simulation framework consists the parameters as given in Table I.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
MAC header	34 byte
PHY header	16 byte
ACK	14 byte
RTS	20 byte
CTS	14 byte
Slot Time	20µs
SIFS	10µs
DIFS	50µs
CW_{min}	31
CW_{max}	1023

We have uses 802.11b PHY for simulation and can handle data up to 11 Mbits/s [2]. In simulation two different types of traffic are used for simulation namely multimedia and FTP/TCP data. Where queues are drop tailed and can capable to accommodate 50 packets.

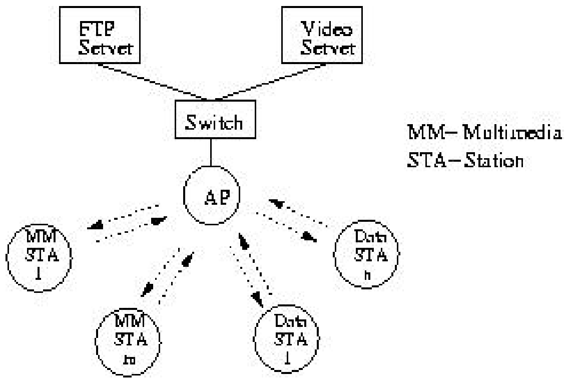

Figure 5. Network topology for simulation

The network topology for simulation is shown in Fig. 5. All the stations can able to handle data rate of 2Mbits/s. Each MM station can generate and receives real-time multimedia data having packet size 1500 bytes but MM stations can receives the FTP. The data stations can generate and receives the TCP/FTP packet with CBR, having packet size 1460 bytes. A video server is there at the wired backbone, where the stored videos are available. It can be access on demand basis. The MM stations can access the it through the Q_q but when data stations try to access the stored video from server, then it has to wait up-to the processing of the BE_q. Once the connection is established then the video server can send data through the Q_q.

To evaluate the throughput and delay of QoSM in comparison to legacy MAC with DCF has described by taking the real-time multimedia data. Only delay is added to the TCP/FTP data packets and analysis is not made for it. According to the parameters described in Table I with the multimedia data packet of size 1500 byte, the Fig. 6 shows the delay analysis between QoSM and legacy MAC DCF.

The delay performance of QoSM +MAC is decreased as compared to the legacy MAC almost 24-25%.

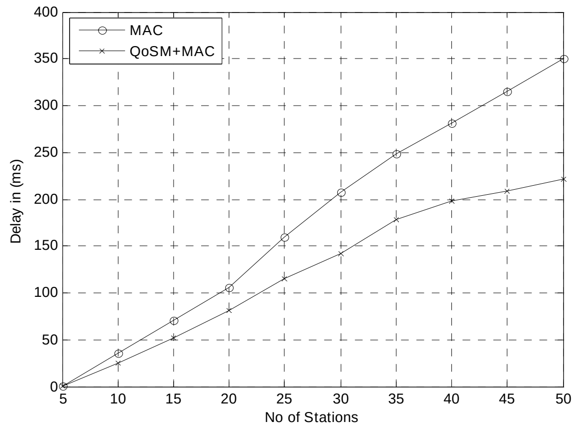

Figure 6. Delay performance Analysis

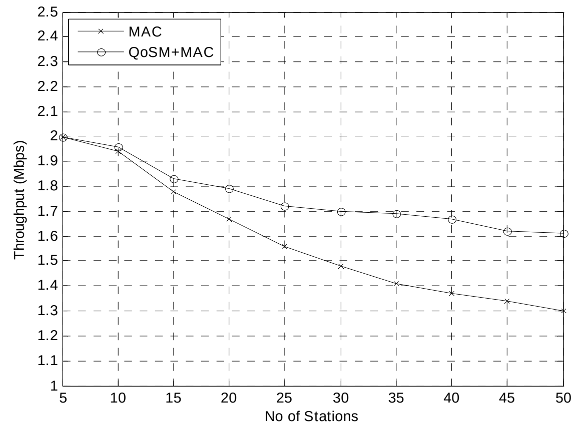

Figure 7. Throughput Analysis

In Fig. 7 the throughput analysis is described between QoSM +MAC and legacy MAC. As delay and throughput are directly proportional, so the decrease in delay affects to increase in throughput. Nearly 24 -25% of throughput is increased by using QoSM scheme as compared to legacy MAC for only real-time multimedia data.

6. Conclusion and Future Work

The QoSM scheme described works before the 802.11 MAC controller so that packets can be separated by QEM and forwarding is being done with a strict priority policy for real-time multimedia packet to achieve the QoS. Based on the simulation, the comparison of legacy 802.11 MAC and the modified MAC with QoSM scheme shows that the delay and throughput can be achieved by 24 –25%. To demonstrate the performance of real-time multimedia data can be enhanced significantly through the QoSM scheme when real-time multimedia and TCP traffic coexists. The reason why a simple scheduling above MAC controller can work surprisingly well is due to the behavior of packet forwarding with a strict priority policy for multimedia real-time data.

7. References

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