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# Modified MAC for Multimedia Wireless LAN Architecture



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***Abstract*—IEEE 802.11 has gained popularity at an unprecedented rate as a simple and cost effective wireless technology for best-effort service. However, it lacks of the capability to support Quality of Services 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 controller. The proposed scheme is verified with the help of ns-2 and an improved performance for multimedia real-time service in the infrastructure-based WLAN with the coexistence of the non-real time traffic.**

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

## I. INTRODUCTION

IEEE 802.11 WLAN has gained the prevailing position in the market for the (indoor) broadband wireless access networking. IEEE 802.11 defines the functionality of medium access control (MAC) layer and physical (PHY) layer specifications for WLAN [13]. 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 [7][8] [13]. WLANs has limited to the non-real-time best-effort services. A wireless multimedia LAN approach has described in [4][5] with DCF with shortened contention window for QoS provisioning and a cross layer framework for QoS support is described in [9]. 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].

In 802.11 a relatively high probability of long packet delays and arises doubts about the efficiency of using legacy MAC DCF for delay-sensitive applications [1]. In this paper we consider a software upgrade-based deployment approach to provide a limited QoS for real-time multimedia service enhancement over MAC controller of 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 II, IEEE 802.11 MAC functionality is briefly reviewed. The proposed QoS Management Strategy is presented in Section III. Section IV discusses the Mathematical Analysis of the model. The performance of the conventional MAC DCF and proposed QoSM with MAC DCF has been studied with network simulator ns2, in Section V, we conclude in Section VI by discussing the future objective of research.

## II. IEEE 802.11 MAC

802.11 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 [13].

MAC works with a single queue first-in-first-out (FIFO) transmission mechanism and is shared by all the traffics [2][8][13]. 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.

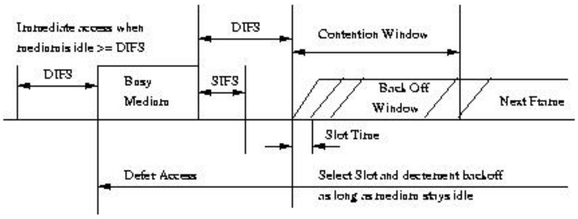


Figure 1. 802.11 DCF access scheme

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. 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.

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). If an ACK packet is not received after the data transmission, the packet is retransmitted after another random backoff [2]. 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.

## III. 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, 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. On arrival of packet 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.

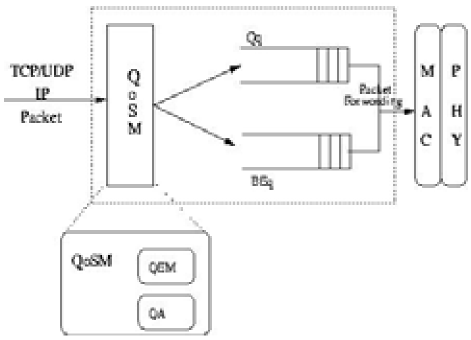


Figure 2. QoS Management Scheme

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 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 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). Proposed scheme uses the source address and packet type to differentiate a multimedia packet and data packet.

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 ($P_i$, $Q_q$) /* Enqueue packet $P_i$ to queue $Q_q$ */*
6. *Else if ($P_t = BE_p$)*
7. *If ($BE_q$ = full)*
8. *Then drop $P_i$*
9. *Else QA ($P_i$, $BE_q$) /* Enqueue packet $P_i$ to queue $BE_q$ */*

*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 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 $BE_q$.

## IV. MATHEMATICAL ANALYSIS

As in Fig. 2 it uses QoSM based on Queue model with two distinguished queue: $Q_q$ and $BE_q$. It follows the preemptive process, i.e. priority packets don't have to wait. As the policy follows a strict priority, so analysis is done only for priority queue. 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 $\lambda$ packets per second having 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 $\mu$ packets per second for states i=1, 2, 3, …N. If N packets in the queueing system, then the requested packet is lost.

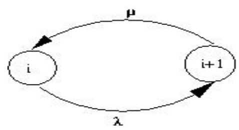


Figure 3. State Transition Diagram of Finite capacity (N) Queue

From the Fig. 3 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= [$p_0$, $p_1$, $p_2$, …$p_n$] 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

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

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

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

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

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

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

### A. *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. Eq (4) gives mean throughput of the queueing system, is a weighted average of service rates. Mean number of packets in the queueing system can found to be

$$\overline{n} = \sum_{n=1}^{N} np_n \qquad (5)$$

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

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

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

### B. *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

$T_{DIFS}$ DIFS time, $T_{SIFA}$ SIFS time

$P_d$ = 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]

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

Data transmission delay

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

Acknowledge transmission delay

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

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

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

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:

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

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

## V. SIMULATION ANALYSIS

Performance analysis of legacy MAC and QoSM a modified MAC is done with the help of ns-2 [6]. The scheme is tested for real time multimedia data stream. Table I shows the parameter for simulation.

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 use 802.11b PHY for simulation that can handle data up to 11 Mbits/s [2]. Two different types of traffic are used, multimedia and FTP/TCP data. Where queues are drop tailed and can accommodate 50 packets.

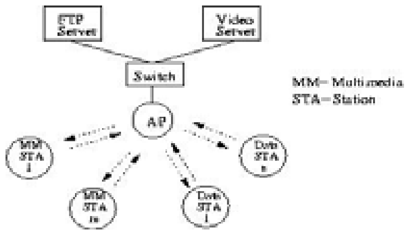


Figure 4. Network topology for simulation

The network topology for simulation is shown in Fig. 4. 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 data. 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. Data stations try to access the stored video from the server, then it has to wait up-to the processing of the $BE_q$. Once the connection is established with the video server, it can send data through the $Q_q$.

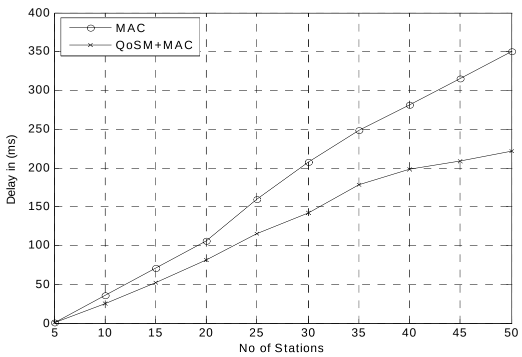


Figure 5. Delay performance Analysis

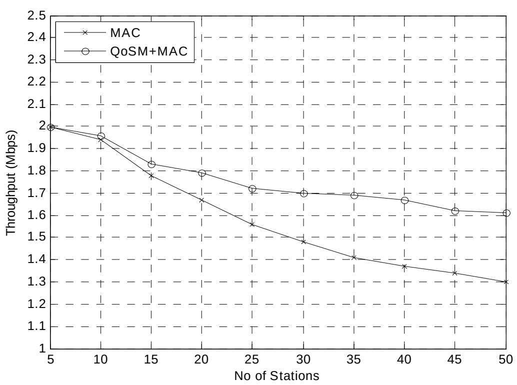


Figure 6. Throughput Analysis

The performance has been analyzed for throughput and delay of QoSM in comparison to legacy MAC with DCF for real-time multimedia data. On progress of transmission delay is added to the TCP/FTP data packets. Based on the parameters described in Table I, with the multimedia data packet of size 1500 byte, the Fig. 5 shows the delay analysis between QoSM and legacy MAC DCF. The performance delay of QoSM +MAC is decreased as compared to the legacy MAC. In Fig. 6 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. The throughput is increased by using QoSM scheme as compared to legacy MAC for only real-time multimedia data.

## VI. Conclusion and Future Work

We proposed a modified MAC scheme based on queueing with strict policy. The QoSM scheme operates on the top of MAC controller. The real-time multimedia packets are separated by QEM and forwarded with a strict priority. The proposed scheme may be deployed for real-time multimedia traffic on the top of the MAC controller. 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 paper is limited to real-time multimedia and video on demand services. This scheme requires further enhancement to support voice traffic.

## References

[1] T. Sakurani, and H. L. Vu, “MAC Access Delay of IEEE 802.11 DCF”, IEEE Transaction on Wireless Communications, May 2007, Vol. 6, pp. 1702-1710.

[2] IEEE, Supplement to Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-speed Physical Layer Extension in the 2.4 GHz Band, IEEE Std. 802.11b-1999.

[3] IEEE Standard, 802.11e/ D 3.1, July 2002

[4] K. Medepalli and F. A. Tobagi,“ System Centric and User Centric Queueing Models for IEEE 802.11 based Wireless LANs,” IEEE 2nd International Conference on Broadband Network, Vol. 1, 3-7 Oct, 2005, pp. 656–665.

[5] K. Kim, A. Ahmed and K. Kim, “A Wireless Multimedia LAN Architecture Using DCF With Shortened Contention Window for QoS Provisioning,” IEEE Communications Letters, Vol. 7 No. 2, Feb 2003, pp.97–99.

[6] S. McCanne and S. Floyed, “NS network simulator,” http://www.isi.edu/ snam/ns, Information Science Institute (ISI).

[7] L. Zhao and C. Fan, “Enhancement of QoS Differentiation Over IEEE 802.11 WLAN”, IEEE Communications Latters, Vol. 8, No. 8, Aug 2004, pp. 494-496.

[8] D. K. Puthal and B. D. Sahoo, “Performance Evaluation of MAC DCF Scheme in WLAN”, Siddhant, A journal of decision making (A Special Issue on Wireless Technology)”, ISSN: 0091/2002- TC, Vol. 7, No. 2, Apr-Jun 2007, pp. 65-75.

[9] G. Pau, D. Maniezzo, S. Das, Y. Lim, J. Pyon, H. Yu and M. Gerla, “A Cross-Layer Framework for Wireless LAN QoS Support”, IEEE International Conference ITRF, Aug 2003, pp. 331-334.

[10] Q. Ni, L. Romdhani, and T. Turletti, “A Survey of QoS Enhancements for IEEE 802.11 Wireless LAN”, Journal of Wireless Communications and Mobile Computing, Wiley, 2004, Vol.4, pp.547-566.

[11] J. K. Choi, J. S. park, J.H. Lee, and K.S. Ryu, “Review on QoS issues in IEEE 802.11 W-LAN”, ICACT 2006, pp.2109-2113.

[12] Y. Xiao, and J. Rosdahl, “Throughput and Delay Limits of IEEE 802.11”, IEEE Communications, Aug. 2002, Vol. 6, pp. 355-357.

[13] IEEE, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, Reference number ISO/IEC 8802-11:1999(E), IEEE Std. 802.11, 1999 edition, 1999.