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An Analysis of QoS Aware Medium Access Channel (MAC) Protocols In Mobile Ad-Hoc Networks

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Abstract- enhance the IEEE 802.11 MAC protocol to support service differentiation. For this various proposed schemes include assigning different inter-frame spaces (IFS), scaling the backoff contention window and assigning different frame sizes according to the traffic priorities. A ravenous problem will impact on the transmission rate for lower priority traffic since much traffic with higher priority is transmitted. Thus the scheme to provide QoS aware MAC protocol should firstly supports fairness to both real time traffic having high priority and non real time traffic having low priority. Secondly, since the demands of such applications are increasing the load on the network so scheme should also consider network congestions. In this paper the comparative analysis of such schemes are considered which provides either fairness or avoid network congestions or both.

Keywords: QoS, MANETs, EDCF, MAC Protocol.

I. INTRODUCTION

1.1 Mobile Ad-Hoc Network

Mobile ad-hoc networks consists of wireless mobile nodes acting as router and/or host and are capable enough to establish wireless network among themselves without any pre-existing infrastructure. There is no need of a system administrator as the nodes are configured to work in ad-hoc network modes. They detect each other's presence in close proximity. The communication is done directly on the basis of peer to peer mode of operation within an independent basic service set (IBSS) network having no central access point. They form an arbitrary topology, where the routers are free to move randomly and arrange themselves as required. The most salient characteristic of an ad hoc network is its dynamic membership. Nodes can join and leave or rejoin the network anytime so the network topology changes with them. The topology of mobile ad hoc networks can potentially change from moment to moment, and there are no "central nodes" that direct or coordinate the activities of all other nodes.

Connection and disconnection is controlled by the distance among nodes and by willingness to collaborate in the formation of cohesive, albeit transitory community [1]. Such a network may operate in a standalone manner i.e. its is not (necessarily) connected to any static (i.e. wired) infrastructure, or may be connected to the larger Internet. The spontaneous networking feature of MANETS that there is no need to run cabling and install networking hardware.

Fig.1 Mobile Ad-hoc Network

The principal applications of ad hoc wireless networks are [2] Military applications, Collaborative and distributed computing, Emergency operations, Automotive networks, Sensor networks

1.2 Quality of Service (QoS)

The ITU Telecommunication Standardization Sector (ITU-T)) recommendation has defined QoS as "The Collective set of service performance which determines the degree of satisfaction of a user of the service". Thus we can say that the goal of QoS is to provide guarantees on the ability of a network to deliver predictable results. For this several key attributes/metrics of QoS need to be considered which include:

- Bandwidth: The transmission capacity of an electronic pathway such as a communications line, computer bus or computer channel. In a digital line, it is measured in bits per second or bytes per second (see Mb/sec).
- Packet loss: The discarding of data packets in a network when a device (switch, router, etc.) is overloaded and cannot accept any incoming data at a given moment
- Delay: This is the delay that a transmitted packet can suffer through the network. If the delay is not constant for a given stream across the network, the receiver not only experiences delay but also jitter in the delay.
- Jitter: It is the variation in delay or response time. It is an important consideration in asynchronous applications
- Mean data rate: This specifies the average data rate, i.e. the amount of data that will be normally sent through the network per unit time, specifying the traffic communication needs in terms of the bandwidth required.

II. NEED FOR SPECIAL MAC PROTOCOLS

The popular Carrier Sense Multiple Access (CSMA) MAC scheme and its variations such as CSMA with Collision Detection (CSMA/CD) developed for wired networks, cannot be used directly in the wireless networks, as explained below. In CSMA-based schemes, the transmitting node first senses the medium to check whether it is idle or busy. The node defers its own transmission to prevent a collision with the existing signal, if the medium is busy. Otherwise, the node begins to transmit its data while continuing to sense the medium. However, collisions occur at receiving nodes. Since, signal strength in the wireless medium fades in proportion to the square of distance from the transmitter, the presence of a signal at the receiver node may not be clearly detected at other sending terminals, if they are out of range. As illustrated in Fig. 2, node B is within the range of nodes A and C, but A and C are not in each other's range. Let us consider the case where A is transmitting to B. Node C, being out of A's range, cannot detect carrier and may therefore send data to B, thus causing a collision at B. This is referred to as the 'hidden-terminal problem', as nodes A and C are hidden from each other [3, 4]. Let us now consider another case where B is transmitting to A. Since C is within B's range, it senses carrier and decides to defer its own transmission. However, this is unnecessary because there is no way C's transmission can cause any collision at receiver A. This is referred to as the 'exposed-terminal problem', since B being exposed to C caused the latter to needlessly defer its transmission [4]. MAC schemes are designed to overcome these problems.

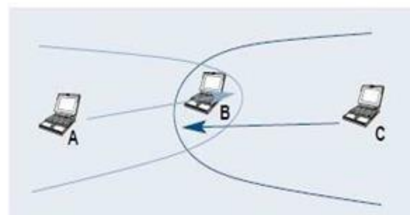

Fig. 2 Hidden and exposed problem

III. BACKGROUND

3.1 Distributed Coordination Function-Mandatory Channel Access in 802.11

The basic 802.11 [5] MAC protocol is the Distributed Coordination Function (DCF) that works as listen before- talk scheme, based on the Carrier Sense Multiple Access (CSMA). Stations deliver MAC Service Data Units (MSDUs) of arbitrary lengths (up to 2304 bytes), after detecting that there is no other transmission in progress on the wireless medium.

However, if two stations detect the channel as free at the same time, a collision occurs. The 802.11 defines a Collision Avoidance (CA) mechanism to reduce the probability of such collisions. As part of CA, before starting a transmission a station performs a backoff procedure. It has to keep sensing the channel for an additional random time after detecting the channel as being idle for a minimum duration called DCF Interframe Space (DIFS), Each station maintains a so-called Contention Window (CW), which is used to determine the number of slot times a station has to wait before transmission. For each successful reception of a frame, the receiving station immediately acknowledges the frame reception by sending an acknowledgement frame (ACK).

The CW size increases when a transmission fails, i.e., the transmitted data frame has not been acknowledged. After any unsuccessful transmission attempt, another backoff is performed with a doubled size of the CW. This reduces the collision probability in case there are multiple stations attempting to access the channel. The stations that deferred from channel access during the channel busy period do not select a new random backoff time, but continue to count down the time of the deferred backoff in progress after sensing a channel as being idle again. In this manner, stations, that deferred from channel access because their random backoff time was larger than the backoff time of other stations, are given a higher priority when they resume the transmission attempt.

To reduce the hidden station problem inherent in CSMA, 802.11 defines a Request-to-Send/Clear-to-Send (RTS/CTS) mechanism, which can be used optionally. Before transmitting data frames, a station has the option to transmit a short RTS frame, followed by the CTS transmission by the receiving station. The RTS and CTS frames include the information of how long it does take to transmit the next data frame, i.e., the first fragment, and the corresponding ACK response. Thus, other stations close to the transmitting station and hidden stations close to the receiving station will not start any transmissions; their timer called Network Allocation Vector, NAV, is set. RTS/CTS helps to protect long data frames against hidden stations.It is important to note that Short Interframe Space (SIFS) is shorter than DIFS, which gives CTS responds and ACKs always the highest priority for access to the wireless medium.

For transmission of multimedia traffic DCF does not meet the QoS requirements. This is because DCF does not support QoS. All the data traffic is transmitted on a first come first serve, best-effort basis. There is no differentiation between data flows to support traffic with QoS requirements. All stations in the basic service set (BSS) contend for the wireless medium with the same priority. When the number of stations in a BSS increases, the probability of collisions becomes higher and results in frequent retransmissions [6], which results in QoS decreases as well as overall throughput in the BSS.

3.2 QoS Support Mechanisms of 802.11e

IEEE 802.11 Task Group E currently defines enhancements to the above-described 802.11 MAC, called 802.11e [6], which introduces EDCF and HCF. Stations, which operate under 802.11e, are called enhanced stations, and an enhanced station, which may optionally work as the centralized controller for all other stations within the same QBSS, is called the Hybrid Coordinator (HC). A QBSS is a BSS, which includes an 802.11e-compliant HC and stations. The HC will typically reside within an 802.11e AP. In the following, we mean 802.11e-compliant enhanced stations by stations. With 802.11e, there may still be the two phases of operation within the superframes, i.e., a CP and a CFP, which alternate over time continuously. The EDCF is used in the CP only, while the HCF is used in both phases, which makes this new coordination function hybrid.

3.2.1 Enhanced Distributed Coordination Function (EDCF)

The EDCF in 802.11e is the basis for the HCF. The QoS support is realized with the introduction of Traffic Categories (TCs). MSDUs are now delivered through multiple backoff instances within one station, each backoff instance parameterized with TC-specific parameters. In the CP, each TC within the stations contends for a TXOP and independently starts a backoff after detecting the channel being idle for an Arbitration Interframe Space (AIFS); the AIFS is at least DIFS, and can be enlarged individually for each TC. After waiting for AIFS, each backoff sets a counter to a random number drawn from the interval [1,CW+1]. The minimum size (CWmin[TC]) of the CW is another parameter dependent on the TC. Priority over legacy stations is provided by setting CWmin[TC] and AIFS=DIFS.

As in legacy DCF, when the medium is determined busy before the counter reaches zero, the backoff has to wait for the medium being idle for AIFS again, before continuing to count down the counter. A big difference from the legacy DCF is that when the medium is determined as being idle for the period of AIFS, the backoff counter is reduced by one beginning the last slot interval of the AIFS period. Note that with the legacy DCF, the backoff counter is reduced by one beginning the first slot interval after the DIFS period. After any unsuccessful transmission attempt a new CW is calculated with the help of the persistence factor PF[TC] and another uniformly distributed backoff counter out of this new, enlarged CW is drawn, to reduce the probability of a new collision. Whereas in legacy 802.11 CW is always doubled after any unsuccessful transmission (equivalent to PF=2), 802.11e uses the PF to increase the CW different for each TC:

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

The CW never exceeds the parameter CWmax[TC], which is the maximum possible value for CW.

A single station may implement up to eight transmission queues realized as virtual stations inside a station, with QoS parameters that determine their priorities. If the counters of two or more parallel TCs in a single station reach zero at the same time, a scheduler inside the station avoids the virtual collision. The scheduler grants the TXOP to the TC with highest priority, out of the TCs that virtually collided within the station, as illustrated in Fig. 3. There is then still a possibility that the transmitted frame collides at the wireless medium with a frame transmitted by other stations.

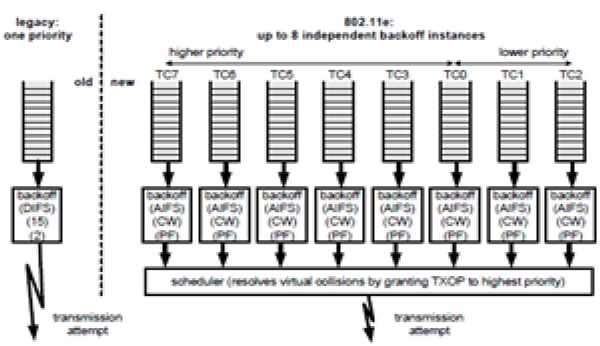

Fig. 3: Virtual backoff of eight traffic categories: (1) left one: legacy DCF, close to EDCF

One crucial feature of 802.11e MAC is the Transmission Opportunity (TXOP). A TXOP is defined as an interval of time when a station has the right to initiate transmissions, defined by a starting time and a maximum duration. TXOPs are allocated via contention (EDCF-TXOP) or granted through HCF (polled-TXOP).The duration of an EDCF-TXOP is limited by a QBSSwide TXOP limit distributed in beacon frames, while the duration of a polled TXOP is specified by the duration field inside the poll frame.

3.2.2 Hybrid Coordination Function (HCF)

In addition the IEEE, Task Group E currently defines enhancements to the above-described 802.11 MAC, called 802.11e. A new access method called Hybrid Coordination Function (HCF) is introduced, which combines functions from DCF and PCF (Point Coordination Function) mechanisms. Enhanced DCF (EDCF) is a contention based HCF channel.

IV. RELATED WORK

Many studies have been devoted to developing MAC protocols in order to deal with real-time applications. One of

the famous MAC protocols is Enhanced Distributed Channel Access (EDCA), which is an enhanced version of DCF and standardized in IEEE 802.11e. EDCA has a capability of quality-of-service (QoS) control by differentiating the size of contention window (CW), the length of arbitrary inter-frame space (AIFS), and so forth. However, EDCA does not fully satisfy the requirement of real-time applications because EDCA does not take care of the permissible latency of applications. To support service differentiation various proposed schemes include scaling the backoff contention window, assigning different inter-frame spaces (IFS), and assigning different frame sizes according to the traffic priorities [7,8]. A starving problem will impact on the transmission rate for lower priority traffic since much traffic with higher priority is transmitted.

Thus the scheme to provide QoS aware MAC protocol should firstly supports fairness to both real time traffic having high priority and non real time traffic having low priority. Secondly, since the demand of such applications are increasing the load on the network so scheme should also consider network congestions. In this paper the comparative analysis of those schemes are considered which provides either fairness or avoid network congestions or both.

The various schemes MMMP [9], T-EDCF[10],PFQAMP[11] and DSPQ[12] are discussed one by one as below.

In this paper [9], the author proposes a new MAC protocol, called Multi-rate Multi-hop QoS-aware MAC Protocol (MMMP) for Ad hoc. It is reservation based asynchronous scheme that provides QoS guarantees for real time traffic by providing service differentiation for various multi-rate real-time traffic and guaranteeing a bounded end-to-end delay for such traffic without starving the non real time traffic. The MMMP uses DCF scheme as basic channel access mechanism and modifications suggested in MMACA/PR. MMMP comprises of four modules:

1. a DCF-like asynchronous MAC scheme,
2. a scheduling scheme, Distributed Priority Scheduling (DPS) algorithm to achieve this.
3. Resource Reservation (RR) scheme to enable flows to have multiple sessions in one cycle, based on their bandwidth requirement
4. To avoid network congestion 'Smart Drop' feature is added to ensure bandwidth conservation by "dropping" packets that are "meaningless" to the network.

Simulation results indicate that MMMP outperforms IEEE 802.11 on all performance measures such as throughput, average delay, number of packets and frames dropped and can efficiently handle a large range of traffic intensity. The simulation results point out in heavily loaded networks, for performance measures the overall MMMP scheme with both smart drop and scheduling is seen to be the best when compared with a pre-existing MAC protocol like MACA/PR. In this paper [10], a novel scheme which adjusts current contention window sizes according to each AC's effect on packet collision rate is proposed. This scheme considers how much each AC traffic affects the packet collision rate. A Traffic-based EDCF (T-EDCF), which is based on the traffic collision rate, expands AEDCF which uses packet collision rate to adjust CW sizes and dynamic service differentiation scheme based on access category (AC)'s traffic flow for QoS provisioning in the IEEE 802.11 wireless local area network (WLAN).

T-EDCF scheme measures current packet collision rate and average packet collision rate as in AEDCF. If collision rate is high, then T-EDCF reduces contention window sizes slowly rather than resetting contention window to CWmin. If T-EDCF sets current contention window sizes to be CWmin, although average collision rate is high, packet collisions will occur more frequently. In other words, by reducing CW sizes slowly, T-EDCF can avoid busty packet collisions. If average collision rate is low, T-EDCF resets CW sizes to CWmin. Using current packet collision rate and average packet collision rate, T-EDCF knows that how much wireless networks are congested and how much each queue's CW sizes have to be adjusted. The performance of T-EDCF is better than EDCF and AEDCF in terms of jitter, delay, and throughput. As the number of nodes increase and collisions occurs more frequently, T-EDCF works more efficiently. Additionally, as the amount of back ground traffic increases, T-EDCF achieves higher throughput, lower jitter, and delay time.

The author [11] proposes a new scheme in which nodes are assigned priorities dynamically new MAC protocol called PFQAMP (Priority based Fairness provisioning QoS-Aware MAC Protocol) which supports QoS for real-time applications and provides fairness in accessing the channel based on

1. Their roles as sender, receiver or forwarding node and
2. Type of the traffic they have to forward or send.
3. The goals of PFQAMP are
   i) To reduce the channel access delay of real-time (higher priority) flows and the end-to-end delay of different flows while forwarding traffic through the network (both real-time and non real-time)
   ii) Assuring the fairness among different traffic flows inside different traffic classes and
   iii) To increase the overall throughput of the network.

To provide a fair access to the network among the neighbor nodes, the source node after a successful transmission of a data packet goes to a lower priority level than the usual. Then neighbor nodes will get a good chance to access the channel. Node in lower priority will come back to normal level after some time periods. The channel access priorities are realized by proper contention window selection method. Besides the fairness and differentiated access mechanisms at MAC layer, proper queuing management scheme is implemented to improve the throughput and fairness at flow level. This queue management scheme not only provides higher priority to real-time packets, but also reduces the possibility of storing old packets for long time.

Two queues are realized one for originated traffic and another for relayed traffic and similar queue management schemes are used in both the queues.

This scheme gives better performance than IEEE 802.11 DCF in terms of end to end delay (ED) and throughput (TP) in all scenarios and in all loads of the network. The throughput increases when the queue size increases in spite of the increase in packet size.
The proposed[12] an enhanced service differentiation mechanism called DSPQ (Differentiation Service based on Per AC Queue).Through adopting traffic conditioning at the entrance of MAC AC queues and maintain collision rate for each AC, DSPQ dynamically adjusts to changing conditions, confining oscillations in throughput and delay. This allows the mechanism to provide strict service differentiation and good flow fairness, while still maintaining a high level of channel utilization. An adaptive MID (Multiple Increase and Decrease) CW update rule with service differentiation based on per flow is used. By employing the MID rule in DSPQ, reaches a tradeoffs between the "collapsing" decrease of CW in EDCA and the "conservative" decrease of CW in MILD which leads unwanted idling, which again reduces throughput. DSPQ out performs 802.11 e EDCA and AEDCF in terms of throughput, collision rate, delay and jitters in all workloads and best in case of medium priority flows.

V. COMPARISON ANALYSIS

The comparative analysis of the four QoS aware MAC protocol techniques discussed above is shown in table 1.

Scheme	**MMMP**	**T-EDFC**	**PFQMP**	**DSPQ**
Queues	Single	Multiple	Multiple	Single
Scheduling Scheme	Priority Based	No	No	No
Congestion Avoidance scheme	Smart Drop	No	Traffic Conditioning	New Mechanism
Fairness	Yes	No	No	Yes
Traffic Source	Real-time and Non Real-time Constant Bit Rate(CBR)/Variable Bit Rate(VBR)	Real-time CBR/VBR	Real-time CBR/VBR	Real-time CBR and VBR
Back-off Algorithm	Binary Exponential Back-off with Static back-off duration	Adaptive Procedure	Adaptive MID CW with update rule	New Back off Timer value
Basic protocol	DCF and MMACA/PR	EDCF	EDCA and AEDCF	Alternative to DCF
Priority Flow	Low and High	High and Low	High, Low, Medium	High(value 0), High(value1), Low(value3), Medium (value2), Normal(No value)

Table 1: Comparison of QoS aware Mac Protocols

VI. CONCLUSION AND FUTURE WORK:

In this paper the comparative analysis of those schemes are considered which provides either fairness or avoid network congestions or both .To support service differentiation various proposed schemes include scaling the backoff contention window, assigning different inter-frame spaces (IFS), and assigning different frame sizes according to the traffic priorities. A starving problem will impact on the transmission rate for lower priority traffic since much traffic with higher priority is transmitted.

Thus the scheme to provide QoS aware MAC protocol should firstly supports fairness to both real time traffic having high priority and non real time traffic having low priority. Secondly, since the demand of such applications are increasing the load on the network so scheme should also consider network congestions.
In future we will try to implement all these algorithms and test them in same environment (traffic model) so as to better analyze the comparative efficiency of these algorithms in real time.

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