IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Performance Evaluation of MAC Protocols based Quality of Service in MANET

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Abstract: Medium Access Control (MAC) protocols play an essential role in wireless communication networks. MAC allows several users simultaneously to share a communication channel in order to achieve maximum of channel utilization with minimum of interference and collisions. Medium Access Control (MAC) protocols are needed in wireless communication networks to allow several users simultaneously to share a common medium of communication in order to gain maximum of channel utilization with minimum of interference and collisions. Various proposed schemes for MAC in Wireless Communication include assigning different inter-frame spaces (IFS), scaling the backoff contention window and assigning different frame sizes according to the traffic priorities. 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. In this paper Performance Evaluation of MAC Protocols based Quality of Service in MANET is presented.

***Index Terms* - CSMA/CA, MANET, MAC, QoS, DCF.**

Introduction

MANET stands for Mobile Adhoc Network also called a wireless Adhoc network or Adhoc wireless network that usually has a routable networking environment on top of a Link Layer ad hoc network.. They consist of a set of mobile nodes connected wirelessly in a self-configured, self-healing network without having a fixed infrastructure. MANET nodes are free to move randomly as the network topology changes frequently. Each node behaves as a router as they forward traffic to other specified nodes in the network. MANET may operate a standalone fashion or they can be part of larger internet. They form a highly dynamic autonomous topology with the presence of one or multiple different transceivers between nodes. Network topology is typically multi-hop may change randomly and rapidly with time, it can form unidirectional or bi-directional links. Wireless links usually have lower reliability, efficiency, stability, and capacity as compared to a wired network. Each node can act as a host and router, which shows its autonomous behaviour. Some or all the nodes rely on batteries or other exhaustible means to get energy. Mobile nodes are characterized by less memory, power, and lightweight features. Wireless networks are more prone to security threats. A centralized firewall is absent due to the distributed nature of the operation for security, routing, and host configuration. They require minimum human intervention to configure the network, therefore they are dynamically autonomous in nature.

Figure 1 shows different types of wireless MAC protocols.

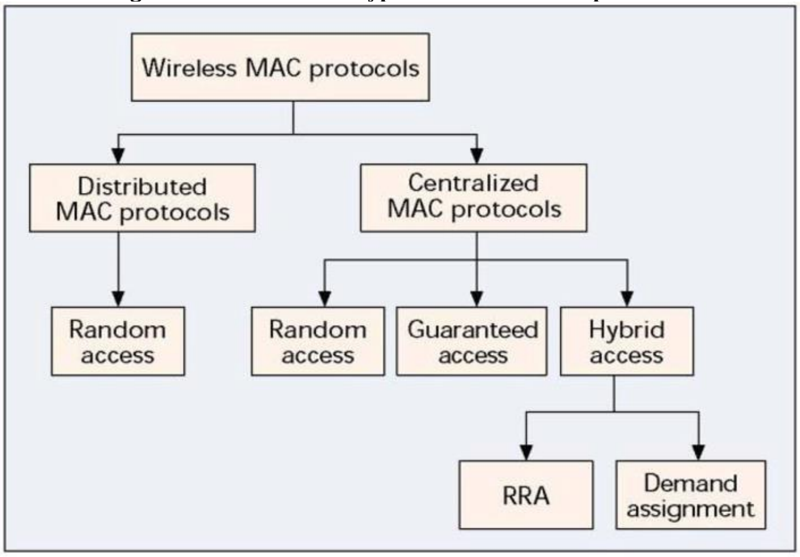

Fig. 1 Wireless MAC protocols

The various Quality of Service (QoS) parameters in Computer Network are as follows:

• Cell Loss Rate (CLR) : It is the fraction of cells that are lost during transmission.

CLR = Cell Lost / Total cells transmitted

• Cell Delay Variation (CDV) : It defines the difference between the maximum and the minimum cell transfer delay.

• Cell Transfer Delay (CTD) : It is the average time required for cell to travel from source to destination. Cell transfer delay is affected by segmentation reassembly and transmission delay.

• Cell Error Ratio (CER) : This parameter defines the fraction of cells that contained errors.

CER = Error cells delivered / Total cells delivered

• Cell Mis-insertion Ratio (CMR) : It is the number of cells inserted per second that are meant for some other destination. It is the ratio of severely error cell blocks to the total transmitted cell blocks.

SECBR = Severely Error Cell Blocks / Total transmitted cell blocks

The factors affecting the QoS parameters are:

- Propagation Delay
- Capacity of Buffer
- Traffic Load
- Allocation of resources
- Architecture of switch present in network
- Media error statistics

The QoS is determined by four parameters which are Reliability, Delay, Jitter and Bandwidth. Technique to achieve Good Quality of Service are :

i. Over Provisioning: Excess of router capacity, buffer space and bandwidth is provided so that packets fly through easily.

ii. Buffering: It smooths out jitter and does not affect reliability or bandwidth. It increases delay.

iii. Traffic Shaping: It forces bursty traffic to be transmitted at a uniform rate.

iv. Resource Reservation: In this bandwidth, buffer space and CPU cycles needed for successful transmission are reserved beforehand.

v. Admission Control: In this a router decides, depending on its current load, whether it should accept or reject a new job.

vi. Proportional Routing: In this, traffic is divided equally amongst all routers so that no single router gets overburdened.

Packet Scheduling: Queuing is used so that an aggressive sender does not block all the lines.

I. MAC PROTOCOLS FOR WIRELESS COMMUNICATION

The popular CSMA (Carrier Sense Multiple Access) MAC scheme and its variations such as CSMA with collision detection designed for wired networks (CSMA/CD) cannot be used directly in wireless networks. In CSMA-based schemes, the sending node first scans the media to see if it is free or in use. If the medium is busy, nodes postpone their transmissions to avoid colliding with existing signals. Otherwise, the node will start sending data while continuing to scan the media. However, there will be a collision at the receiving node. Signal strength in the wireless medium decreases with the square of the distance from the transmitter, so the presence of a signal at a receiving node cannot be reliably detected by other transmitting devices that are out of range. Distributed Coordination Function (DCF) MAC protocol that operates as a listen-before-talk scheme based on Carrier Sense Multiple Access (CSMA). A station delivers MAC Service Data Units (MSDUs) of arbitrary length after detecting no other transmissions on the wireless medium. However, if two stations think the channel is free at the same time, a collision occurs. A Collision Avoidance (CA) mechanism is defined to reduce the likelihood of such collisions. As part of CA, a station performs a backoff procedure before starting transmission. After determining that the minimum duration channel, called the DCF Interframe Space (DIFS), is clear, an additional random time channel should be sampled. Each station maintains something called a contention window (CW) that is used to determine how many slots the station should wait before transmitting. Each time a frame is successfully received, the receiving station immediately acknowledges receipt of the frame by sending an acknowledgment (ACK) frame. A failed transmission increases the CW size. H. A transmitted data frame was not acknowledged. Each unsuccessful transmission attempt causes another backoff of twice the size of the CW.

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. 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].

II. Analysis of QoS in Wireless MAC Protocols

The popular CSMA (Carrier Sense Multiple Access) MAC scheme and variations such as CSMA with collision detection designed for wired networks (CSMA/CD) cannot be used directly in wireless networks. In CSMA-based schemes, the sending node first gets the media to see if it is free or in use. If the medium is busy, the node will postpone transmission to avoid colliding with existing signals. Otherwise, the node will start sending data while continuing to scan the media. However, there will be a collision on the receiving node. Signal strength in the wireless medium decreases with the square of the distance from the transmitter, so the presence of a signal at a receiving node cannot be reliably detected by other transmitting devices that are out of range. Therefore, schemes for providing QoS-aware MAC protocols must first support fairness for both high-priority real-time traffic and low-priority non-real-time traffic. Second, the network congestion must also be taken into account with this method, as the demands of such applications increase the load on the network. This white paper considers a comparative analysis of these schemes that either provide fairness, avoid network congestion, or both.

Multi-rate Multi-hop QoS-aware MAC Protocol (MMMP) for Ad hoc Network is reservation based asynchronous scheme that provides QoS guarantees for real time traffic by providing service differentiation for various multi-rate realtime 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 further modifications have been suggested in MMACA/PR. According to the results of the simulation, MMMP performs better than IEEE 802.11 on every performance metric, including throughput, average delay, number of packets and frames missed, and is capable of handling a wide variety of traffic intensities. The simulation findings show that when compared to an existing MAC protocol like MACA/PR, the entire MMMP scheme with both smart drop and scheduling is proven to be the best for performance metrics in densely congested networks.

T-EDFC scheme is presented, in which current contention window adjust sizes according to each AC's effect on packet collision rate. 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. The T-EDCF method, like AEDCF, measures the current packet collision rate and the average packet collision rate. When the collision rate is high, T-EDCF slowly reduces the contention window size instead of resetting the contention window to CWmin. T-EDCF provides higher throughput, lower jitter, and lower latency.

Further another scheme has been proposed 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 their roles as sender, receiver or forwarding node and type of the traffic they have to forward or send. 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 goals of PFQAMP is to Assure the fairness among different traffic flows inside different traffic classes and to increase the overall throughput of the network and 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)

After a successful data packet transfer, the source node switches to a lower priority level than usual to ensure that neighbouring nodes have equal access to the network. Neighbor nodes will then have a fair opportunity to access the channel. After a certain amount of time, a node with a lower priority will return to its previous level. By using the right selection mechanism for the contention window, the channel access priorities are realised. Along with the fairness and differentiated access controls at the MAC layer, a suitable queuing management strategy is put into place to increase throughput and fairness at the flow level. Real-time packets are given a higher priority under this queue management technique, which also lessens the likelihood of keeping old packets around for an extended period of time.

Another scheme is based on service differentiation mechanism called DSPQ (Differentiation Service based on Per AC Queue). By handling traffic conditioning at the ingress of MAC-AC queues and maintaining collision rates for each AC, DSPQ dynamically adapts to changing conditions and limits variations in throughput and latency. This allows the mechanism to maintain high levels of channel utilization while providing strong service differentiation and excellent flow fairness. 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.

III. COMPARITIVE ANALYSIS

The comparative analysis of four QoS aware MAC protocol techniques is presented here :

- Queue is single in MMMP and DSPQ whereas in T-EDFC and PFQMP it is multiple.
- Scheduling Scheme is priority based in MMMP but in other 3 schemes it has no priority based system.
- Congestion avoidance scheme is Smart drop in MMMP, Traffic conditioning in PFQMP, new mechanism in DSPQ and it is not available in T-EDFC
- Fairness Scheme is used in MMMP and DSPQ, whereas in it is not used in T-EDFC and PFQMP.
- MMMP uses Real-time and Non Real-time Constant Bit Rate(CBR)/Variable Bit Rate(VBR) traffic source whereas T-EDFC, PFQMP and DSPQ uses Real-time CBR/VBR traffic.
- Type of backoff algorithm used is Binary Exponential Back-off with Static back-off duration in MMMP, adaptive procedure in T-EDFC, Adaptive MID CW with update rule in PFQMP and New Backoff Timer values in DSPQ.
- Basic protocol used is DCF and MMACA/PR in MMMP, EDCF in T-EDFC, EDCA and AEDCF in PFQMP and Alternative to DCF in DSPQ.
- Priority Flow used in MMMP is Low and High, T-EDFC is High and Low, PFQMP is High/Low/Medium and in DSPQ is High(value 0), High(value1), Low(value3), Medium(value2), Normal(No value).

IV. CONCLUSION

In this paper, the need for MAC mechanism and the MAC protocols implemented for various wireless network is presented. The comparative analysis of those schemes are considered which provides either fairness or avoid network congestions or both. The comparative analysis of four QoS aware MAC protocol techniques is presented. It is found that 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. Comparitive analysis is presented on the basis of queue, scheduling, fairness, traffic, backoff algorithm etc.

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