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A STUDY OF IEEE 802.11E WLAN WITH RESPECT TO QOS ISSUES

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ABSTRACT

Today, the world is highly developed with the vast technological advancement. Several types of networking technology are available such as the wired networks, wireless networks, etc. Within wireless networks, there are ample technologies which are highly sophisticated and advanced. IEEE 802.11 standard is one among the most researched protocols, and in IEEE 802.11 protocol, the IEEE 802.11e protocol is highly promising and have emerged at a rapid pace. This standard has several advantages. But, still faces various QoS issues while deployment and utilization. Although there are several works on QoS in IEEE 802.11e WLAN, there is an absence of a comprehensive performance study that provides a detailed description related to the QoS enhancement techniques in IEEE 802.11e WLAN. In this paper, we present a detailed study of IEEE 802.11e WLAN, its QoS issues, various mechanisms to enhance the QoS requirements. A comparison table is presented to summarize the features of each techniques, its advantages and corresponding drawbacks.

KEYWORDS: *IEEE 802.11e, WLAN, QoS, Protocol, CSMS/CA*

I. INTRODUCTION

1.1 IEEE 802.11 Protocol

IEEE 802.11 (802.11) WLAN is emerging as one among the successful technology due to some of its excellent features like simplicity, robust nature, etc which is a result of its distributive network nature [1].

IEEE developed the IEEE 802.11 specification exclusively for the Wireless LAN networking. The WLAN technology functions at 2.4 GHz ISM band or else in the 5 GHz UNII band. Several groups are created in order to improve the IEEE 802.11 technology in the MAC or PHY layer since its initial release. Some of the important revisions made in IEEE 802.11 are:

1) 802.11b: functions at a frequency band of 2.4 GHz with direct sequence spread spectrum (DSSS) technology. Its data rate varies from 1 to 11 Mbps.

2. 802.11a: functions at a frequency band of 5GHz with orthogonal frequency division multiplexing (OFDM) technology. Its data rate ranges upto 54 Mbps.

3. 802.11g: functions at a frequency band within 2.4 GHz with orthogonal frequency division multiplexing (OFDM) technology. Its data rate ranges upto 54 Mbps.

In IEEE 802.11 MAC, the data packets can be transmitted in either of the two methods:

1. Distributed Coordination Function (DCF): on the basis of CSMA/CA and

2. Contention-free Point Coordination Function (PCF): the Access Point handles all transmissions on the basis of polling technique.

In a superframe, the DCF and PCF modes are combined such that at fixed intervals of time the PCF contention free period (CFP) is succeeded by the DCF contention period (CP). The terminals are provided with the management details on a regular interval by the AP through beacon frames. The Delivery Traffic Indication Message (DTIM) in the beacons draw a boundary between the CFP and CP.

The beacon information is utilized by the terminals to link with the AP at the CP. This linking becomes necessary if the terminal transmission requires PCF scheduling. This is seen in case of QoS sensitive data transmission [2].

1.1 Interframe Spaces

The Interframe Spaces (IFS) length are critical in determining the packet priority. There are three types of IFS. They are:

1. SIFS (Short IFS): This IFS is short in length and is mainly utilized for transmitting frames of high priority. Example of high priority frames are acknowledgements of DATA frames, CTS frames, PCF frames and all DCF DATA frames excluding the foremost fragment of a data burst.
2. PIFS (PCF IFS): This IFS is larger than SIFS. After the expiration of the PIFS period, the transmission of the PCF mode frames occurs.
3. DIFS (DCF IFS): This IFS is larger than PIFS. After the expiration of the DIFS period, the transmission of the DCF mode frames occur asynchronously based on the CSMA back off technique [2].

1.1.2. Distributed Coordination Function (DCF)

In the DCF mode, the “listen-before-talk” mechanism is used according to the CSMA/CA technique. In this technique, the terminals keep listening to the medium to in order to check when it becomes free. A station which needs to transmit data packets, if it finds the medium to be busy, then it will reschedule its transmission and then start a backoff counter. Any number within the interval ranging from 0 to contention window (CW) can be set as a value of the back off counter. The backoff process is initiated when the station finds the medium free upto DIFS. In the backoff process, the counter is decremented until the channel is found to be idle. The station initiates transmission when the counter value becomes equal to zero and if the channel is still idle. While decrementing the backoff counter, if the channel becomes busy, then the backoff counter stops decrementing. It reinitiates the decrementing process after network allocation vector (NAV) period. The NAV period information is stored in the header of the winning station’s packet.

If two or more stations start data transmission simultaneously, then it results in collision. In case of collision, the transmitting station does not receive any acknowledgement (ACK) from the receiving station. Once, collision is detected by the stations, all the related stations increase their CW by two times the initial CW length and try to get hold of the channel. When a station attains channel access, it receives the ACK from the receiver, and then the transmitting station reduces its CW to CWmin. In DCF mode, all the stations try to access the same channel and have equal priority, thus fails to offer QoS aid, as there is no specific scheme to distinguish stations as well as the traffic type [3].

1.1.3. Point Coordination Function (PCF)

In PCF, the data transmission carried out is contention free. The time is differentiated into superframes which contains a contention period (CP) and a contention free period (CFP). In CP, the DCF is utilized and in the CFP, the PCF is utilized. In the superframe, the initial part is the beacon management frame. This initial frame is transmitted by the AP. The AP basically functions as a point coordinator. The target beacon transmission time (TBTT) is the time required by the AP to create beacon frames. This TBTT is given by the previous beacon frame. The PCF offers high priority to the point coordinators by employing the PIFS, which is smaller than the DIFS but at the same time greater than the SIFS.

AP uses the polling list to poll its member stations during CFP. Only the polled stations are permitted to transmit its data. If a polled station has no data to be transmitted, then a null frame containing no payload is transmitted. If the AP transmits a CF end message, then the CFP is terminated. If polling of all the stations was not completed during CFP termination, then during the next CFP cycle, the polling list is resumed from the point where the last polling process stopped. The AP may either poll the consecutive station or terminate CFP, if it does not get any reply from the polled station. Thus, ensuring that all the idle interval is shorter than the PIFS.

When considered in comparison with DCF, the PCF is very sophisticated and also needs centralized controlling. PCF faces issue in providing QoS aid. For instance, PCF faces an irregular beacon delay issue. This is because, in case there exists an incomplete DCF frame in the previous subframe, then a delay has to be included before transmitting a beacon. Also, since a polled station can select any frame of size varying from 0 to maximum MAC service data unit (MSDU) size, it becomes very hard to predict the transmission time of the involved polled station [3].

1.2 IEEE 802.11e Protocol

The IEEE 802.11e is an improvised version of the fundamental IEEE 802.11 MAC which is being standardized. This version exclsively provides QoS.
QoS is ensured by IEEE 802.11e by employing the priority scheme. When compared wth the original version, IEEE 802.11e does not consider all the data packets with same priority. In IEEE 802.11e, on the basis of the QoS needs, the data packets are prioritized. For data belonging to every priority, there are four Access Categories (AC). On the basis of the data priority, medium access is offered, in such a way that data with specific priority is linked to a specific AC. The contention for the medium is based on specific contention factors for every AC, and accordingly service is differentiated.
In IEEE 802.11e, the AP rendering the QoS service is called as QAP (QoS Access Point), the STA rendering the QoS service is known as QSTA (QoS Station), the operating BSS is known as QBSS (QoS Basic Service Set).
To offer QoS aid, the IEEE 802.11e have developed a coordination function known as the Hybrid Coordination Function (HCF) [3].

1.2.1 Hybrid Coordination Function (HCF)

HCF is a coordination function which is centralized unlike distributed. HCF offers service differentiation by incorporating the features of both DCF and PCF along with improvised QoS schemes. HCF provides two kind of channel access: distributed channel access and centralized channel access as seen in DCF and PCF. In HCF, Enhanced Distributed Channel Access (EDCA) is the distributed channel access scheme which is contention based and HCF Controlled Channel Access (HCCA) is a centralized channel access scheme which is contention free based.
In IEEE 802.11e, Transmission Opportunity (TXOP) is the time interval during which the QSTA can perform data transmission or when a network station has channel access. TXOP has a start time and an end time. The end time is called as the TXOP limit and it is announced by the QAP. The QSTA/ station can perform data transmission upto TXOP limit.

1.2.2 Enhanced Distributed Channel Access (EDCA)

Based on the data priority assigned to each type of data, EDCA allots different, distributed access to the channel.

- **Access Categories (ACs)**

For different kind of data, EDCA has four AC. The service differentiation is performed so as to ensure that for every AC, a separate feature set is utilized for medium contention and these feature sets are called as EDCA parameters. Based on the QoS needs of each data frame, each data is linked to a separate AC.

The four Access Categories are given below

1. AC_BK for Background data traffic
2. AC_BE for Best Effort data traffic
3. AC_VI for video data traffic
4. AC_VO for Voice data traffic

The AC_VO has the highest priority among all and AC_BK has the lowest priority. When a frame arrives at the MAC layer from its previous layer, it carries its priority value which is considered as User Priority (UP). The UP is allocated based on the frame traffic type. The priority value ranges from 0 to 7.

Priority allotment to every frame in the data traffic is the issue to be handled by the higher layer. Usually, priority in the higher layer can be allotted by the application which creates the data traffic or by the application user. When the priority is assigned by the user, then in order for the application to be used in IEEE 802.11e, it needs to be updated. It is also possible to dynamically allot the priority at the application layer depending on some factors such as packet size, data rate, etc. Based on the UP, the frame is assigned with a specific AC at the MAC layer [3].

1.2.3 Enhanced Distributed Channel Access Function (EDCAF)

Four transmit queue, one for each AC is generated at each station and then four EDCAFs are maintained for each queue. EDCAF is an improvised adaptation of the original DCF and it functions by contending for the medium in a similar manner as in CSMA/CA and backoff [4].

1.3 QoS issues in IEEE 802.11

1.3.1 QoS limitations of DCF

1. DCF can aid just the best effort services and not every QoS requirements.
2. Some of the time bound operations like VoIP, video as well as audio conference have very strict bandwidth requirement, experience delay and jitter, loss tolerance is very less, etc.
3. In DCF, every station within a BSS or every flow related to one station contend with one another for the network resources and also for channels which have equal priorities. So, there is a scheme to ensure bandwidth, lower delay, etc for the higher priority stations.
4. Contention for channel access for longer time results in reduced throughput and increased delay.
5. QoS assurance of the high priority station is not possible as the medium shared is of the same priority.
6. As the medium used are of equal priority, there will be an exponential increase in packet drop rate, jitter and delay [5].

1.3.2 QoS limitations of PCF

The IEEE working group developed the PCF inorder to aid the time compliant multimedia operations. However, it still faces three main issues that causes low QoS.
1. With the increase in the data traffic load, the PCF high priority traffic performance degrades due to the ineffective and sophisticated centralized polling mechanism involved. Also, in some cases of home networking, only a direct connection between television (TV) and computer is necessary. However in the PCF mode in IEEE 802.11, every communication has to pass through AP, which reduces the bandwidth utilization.
2. Beacon delays are often seen due to reduced cooperation between the CP and CFP. The Point Coordinator (PC) assigns the beacon as the immediate next frame for transmission during the Target Beacon Transition Time (TBTT). If the medium is detected to be idle for more than the PIFS time, then the beacon is transmitted. The delay in beacon transmission is dependent on the state of the medium: idle or busy during the TBTT. The delay in the beacon transmission during the TBTT, affects the delivery of the time-bound MSDUs (MAC Service Data Unit) in the CFP mode. However in the present IEEE 802.11 version, though the MSDU transmission is incomplete prior the following TBTT, the stations can begin its data transmission. This leads to delay which in turn results in degraded QoS in every CFP.
3. It is not possible to determine the time involved in data transmission by the polled stations. Fragmentation of the frames is permitted in polled stations prior data transmission. In IEEE 802.11a, several modulation mechanisms and other related mechanisms are employed which alters the MSDU transmission time, and is uncontrollable. Hence, QoS assurance cannot be provided by PC to stations which are polled at the later part of CFP [5].

II. LITERATURE REVIEW

Qiang Ni et al [6] have presented the QoS limitations of the original IEEE 802.11 wireless LAN MAC layer. In this paper, various QoS enhancement mechanisms that are developed for IEEE 802.11is discussed, analyzed and categorized. Out of the several techniques developed to improve the QoS in IEEE 802.11, queue based IEEE 802.11e version is very efficient. However, further evaluation of this version is necessary. The drawbacks in IEEE 802.11 is related to dynamically adjusting the traffic features according to the current load as well as the channel status in the EDCF mode, handling channel proficiency, fairness as well as priority in a fair manner, analyzing the EDCF packet burst and contention free burst with respect to efficiency and performance, linking various IP Diffserv (AF, EF), Intserv priorities as well as the IEEE 802.11e MAC priorities, etc.

Lassaâd Gannoune et al [7] have presented the 802.11 protocols and analyzed QoS limitations.These protocols just offer best effort service to its users. The presented QoS mechanism improve the DCF accessing technique and allots high priorities to specific stations to ensure differentiated service. This paper presents the important characteristics of the IEEE 802.11e version and then the EDCF and HCF are considered as the important medium accessing techniques. To ensure QoS, differentiated service and guaranteed service are considered as the fundamental need. This paper also discusses various issues faced in IEEE 802.11e.

Aqsa Malik et al [8] have surveyed several QoS improvement mechanisms developed for IEEE 802.11 networks. Then these mechanisms are analysed with respect to the conventional architectures available and also with new architecture like SDN, cloud networks, etc. The mechanisms are then categorized based on various network performance features. Most of the QoS improvement techniques developed for the TCP/IP layer are analyzed with the other related cross layered protocols. The major limitation observed is the inability to perform IEEE 802.11e testing with respect to various QoS needs and various situations.

Fedoua Didi et al [9] have surveyed the IEEE 802.11 protocol along with the IEEE 802.11e version. It is confirmed that just best effort services can be aided by DCF and hence is not able to provide QoS assurances. In the DCF mode, all the network resource and channels have equal priority and hence every station contend for equal priority resources and channels. Thus, it is not possible to assure bandwidth, reduced delay and jitter for the stations with higher priority. The EDCA protocol is very efficient in handling the high priority traffic. However, this protocol makes the low priority traffic to suffer at times of high traffic load in the network due to collisions. When the load is very high, then the audio and video throughput reduces and thus necessitates an admission control scheme for audio as well as video traffic when the traffic load is very high. In HCCA, queue weights are not computed appropriately, which traffic flow is not balanced in terms of priority. Overall, it is seen that IEEE 802.11e is more efficient when compared with IEEE 802.11.

Gaurav Sharma et al [10] have presented the performance of contention based medium access control (MAC) protocols. In these protocols, the throughput and related factors are computed based on a new scheme, which is developed according to the Markovian framework analysis. Based on this study it is seen that in the bigger network with restricting characteristics, the back off stage stochastic evolution at various stations turns into a deterministic evolution, which has a fixed point that is unique. In this way, this paper offers explains the MAC protocol effect on the network operation.

Muhammad Akber Farooqui [11] have developed an expression to estimate the starvation level of each AC during each traffic load case as well as with specific channel access factors like AIFSN allotted to every related channel. The traffic load is also affected by the some other differentiation factors. The AP can predict the time interval during which starvation point will be experienced in each AC based on the channel load and AIFSN allotted to every AC. This prediction is not dependent on the condition if the AC packets are transmitted or not. Additive aid is necessary to provide improvement in the performance.

III. SURVEY OF EXISTING TECHNIQUES

In this section, various techniques for improving QoS in WLAN network is discussed. These analyses encompass the key concept, performance metrics used, advantages and limitations of the existing resource allocation mechanism. Analyses can help to understand how the techniques are implemented in the IEEE 802.11 WLAN networks.

3.1 Scheduling techniques for Improving QoS

In this section, some of the scheduling techniques for enhancing the QoS in WLAN network is discussed.

3.1.1 Wireless Timed Token Protocol (WTTP)

WTTP is a scheduling algorithm which operates centrally depending on the round robin mechanism. WTTP is used in handling the multimedia traffic in IEEE 802.11e networks through HCCA. The estimation sophistication in WTTP is O(1) per packet and it is dependent on the TS number. However it supports traffic data admission in both CBR and VBR and also provides rate guarantees. The packet creation format in both CBR and VBR and also the packet creation time interval is utilized by the WTTP to develop a good bandwidth sharing as well as polling technique. To maintain lesser delays, the VBR TS are given additional bandwidth. This is useful even when the present data rate crosses the mean reserved data rate value on a temporary basis. Also, prior expiration of the full packet generation time period, the QAP will not start polling the uplink TS if it is observed to be an empty buffer [12].

3.1.2 Token Based Scheduling Scheme

The token-based scheduling scheme handles voice traffic as well as data traffic and is basically a distributed mechanism. For data traffic, the token-based scheduling scheme offers quantitative and accurate service differentiation, whereas for the voice traffic the token-based scheduling scheme offers assured priority access. As a result, service provider can function in a robust manner. In a completed linked WLAN, the token-based scheduling scheme offers quantitative service differentiation and fairness. In the token-based scheduling scheme, QoS is assured by employing the call admission control (CAC) scheme for the voice traffic as well as for the data traffic. But, resource loss may be seen due to the deployment of the call admission control (CAC) [13].

3.1.3 Feedback based controlled scheduling

In IEEE 802.11e, the issue of bandwidth allotment to the first hop based on HCCA function is handled using the Feedback based controlled scheduling technique. This technique is a control theoretic framework. In this technique, CAC mechanism is used and two robust bandwidth allotment algorithm: FBDS and PI-FBDS are employed. The employed two algorithms are capable of handling the network with lower delays even when the traffic load is very high. However, this scheduling technique attains fairness between one way packet delay as well as higher traffic load by employing the PI-FBDS [14].

3.1.4 Enhanced Fair Scheduling

Enhanced Fair Scheduling (EFS) technique is an effective scheduling technique which works with distributed approach and maintains fairness in its operation. In IEEE 802.11e, weighted fair scheduling is aided by the EFS mechanism, which aims at attaining impartial bandwidth allotment as well as improvised throughput. The highest priority in EFS is gained by the packet with minimum ratio between the packet length and its weight. In this mechanism, the backoff time period is selected in symmetry with the finish tag of the data packet. It is possible to attain good bandwidth allotment mechanism by selecting a proper backoff time period and also by employing a effective collision avoidance technique. Further improvement in the network performance can be seen by employing a quick backoff scheme in backoff timer decrement state as well as by robustly adapting the backoff time period on the basis of the traffic load [15].

3.1.5 Adaptive Fair Distributed Scheduling

Adaptive Fair Distributed Scheduling algorithm (AFDSA) is a scheduling algorithm which is non centralized and is developed majorly for the IEEE 802.11e. Three new parts are appended to the RTS/CTS frame by this algorithm in order to ensure QoS. The first channel access is based on the EDCA scheme. During the time period when the channel is reserved for a specific station, the remaining stations contend to gain channel access for the time which is still not reserved for any station. This algorithm ensures QoS for both kind of video traffic: VBR and CBR. When linked to the backbone of the network, every node can function as a AP and hence there is no requirement for a point coordinator [16].

3.1.6 Packet Scheduling

In IEEE 802.11e HCCA, the scheduling technique that is mainly developed for audio and video transmission is the packet scheduling technique. Application level QoS can examined using the packet scheduling technique by considering network performance features such ass SI, retransmission limit and the station strength. It is observed that in the TGe mechanism, the received MSDU number in SI is usually lesser than the predicted number. The packet scheduling technique enhances the QoS in the TGe mechanism since extra bandwidth is used by the AP to assign additive TXOP period depending on the number of the retransmission to overcome the lack of bandwidth. This technique also supports the admission control process in noisy network scenario [17].

3.1.7 Immediate Dynamic TXOP HCCA (IDTH)

Immediate Dynamic TXOP HCCA (IDTH) is a new scheduling algorithm based on bandwidth reclaiming mechanism which cooperates with a HCCA real-time scheduler. IDTH recovers the fraction of the transmission time unused by the scheduled stations to provide additional capacity for the next variable bit rate (VBR) traffic streams. The TXOP of the next scheduled station is assigned by checking the available spare resources and the previously used ones [31].

3.2 Admission control techniques for Improving QoS

In this section, few admission control techniques for enhancing the QoS in WLAN are discussed.

3.2.1 MAC QoS based admission control

The MAC QoS based admission control technique is responsible for robust rescheduling of the data packets depending on the deadlines as well as the traversing hop length. This technique helps the data packets with stringent deadlines as well as longer hop length to arrive at the respective destination within the predetermined deadline, in turn enhancing the PDR. Next channel access count is minimized by adjusting the TXOP robustly so that every fragment belonging to a single video frame gets transmitted in one burst [18].

3.2.2 Collaborative scheme for Admission control

The Collaborative scheme for Admission control technique basically links IEEE 802.11e MAC, the IEEE 802.11 Wireless Local Area Network (WLAN) standard with an network QoS topology on an end to end level. Every QoS mechanism in the transport level is linked with the various network interfaces such as DiffServ in network and 802.11e and 802.1D/Q in link layer. Based on the analysis, it is observed that each QoS mechanism have three procedure: traffic categorization, marking and forwarding. Since, this observed procedure is common in all the QoS technique, lesser compatibility between QoS traffic factors is enough to describe an end to end QoS architecture [19].

3.2.3 Adaptive QoS Admission Control

The IEEE 802.11e standard QoS features are enhanced by the adaptive QoS admission control technique. This control technique permits the traffic data to stipulate the lower and higher QoS needs such that the QoS states of the current and the upcoming traffic can be robustly adapted by the AP [20].

3.2.4 EDCA and HCCA based admission control

The EDCA and HCCA based admission control mechanism utilizes the average of the data rate estimated over a long term to perform admission control and the instant rate value to perform TXOP allotment to every station. Thus, maximum flows are permitted using this mechanism when compared with the conventional mechanisms, and also there is no deterioration in the network performance of each station as the TXOP is estimated based on the instant rate value. However, there are instances when some packets will get dropped. For instance, if many stations relocate to places which is away from the AP, then there will be lack of resources to handle data transmission and so resulting in packet drop. To overcome such scenario, arbitrary QoS sessions are chosen and its TXOP is minimized for each packet [3].

3.2.5 QAP based admission control Technique

The QAP based admission control Technique is used to guarantee proper use of the network resources and QoS. This mechanism overcomes the load instability issue between the QAP involved with BSS. The inter QAP communication process within bigger WLAN is deployed along with the admission control unit in EDCA. QoS management techniques developed on the basis of the inter QAP differentiation causes proper use of the resources by relocating the QSTA from highly loaded region to minimally loaded QAP. This assures QoS for different traffic kinds [28].

3.2.6 Effective Call Admission and Rate Control Scheme

In call admission control algorithm, when accepting a new real-time flow, the algorithm considers its effect on the channel utilization and the delay experienced by existing real-time flows. The algorithm assures that the channel is not overloaded and the delay requirements are not violated. In rate control algorithm, the best effort traffic is allowed to fully use the residual bandwidth of the real-time traffic. It achieves high channel utilization [29].

3.3 Channel access provisioning techniques for Improving QoS

In this section, some of the channel access provisioning techniques for enhancing the QoS in WLAN network is discussed.

3.3.1 Weighted Fair Uplink/Downlink Access Provisioning

The Weighted Fair Uplink/Downlink Access Provisioning mechanism is basically a robust EDCA parameter adaptation algorithm. This mechanism maintains the priority between the AC and also attains the predefined utilization ratio among the uplink and downlink traffic flow. The major advantage of this mechanism are: this is a unique mechanism as the EDCA factors are robustly adjusted based on the estimation depending on the active link count as well as the utilization ratio. The EDCA features are estimated such that the pre estimated utilization ratio between the two links: uplink and the downlink is attained. Also this technique distinguishes the pattern in UDP and TCP for the process of weighted fair access provisioning. This mechanism ensures fair and balanced assignment of the resources and also maintains QoS [21].

3.3.2 Asymmetric Access point based channel access provisioning

In Asymmetric Access point based channel access provisioning technique, the TXOP is allotted among AAP as well as stations which aid proficient functioning of the TCP network in IEEE 802.11 WLAN. There is a need for the AP downlink queue to be empty when the AP has access to the channel, to ensure that the TCP links can function and achieve its required functionality where the destination node handles the flow rate. This allows the network to overcome lesser throughput and longer delay issues, and enhance the network performance with respect to the throughput, delay, etc [22].

3.3.3 Channel Access Throttling

To enhance the WLAN QoS, which works according to the principle in which the channel access differentiation control of EDCA is increased from one dimension, different AC to two additive dimension, different stations with different time. Due to this, CAT is capable of functioning in a dynamic manner and attain the predefined system design targets. The channel access technique of EDCA is united by CAT by scheduling the access. Thus, CAT technique is advantageous to EDCA systems that can only aid differentiated service QoS, by making use of the scheduled access. The channel resource is divided in a balanced manner by CAT technique and maximizes the channel capability by enhancing the channel access proficiency [23].

3.4 Enhancing IEEE 802.11e MAC protocol for Improving QoS

In this section, a technique for enhancing the IEEE 802.11e in order to improve the QoS in WLAN network is discussed.

In WLAN, the IEEE 802.11e version is a very strong tool due to its effective MAC layer QoS schemes for the RT operations. There are several coordinate functions like EDCA and HCCA. But the EDCA is not capable of ensuring any QoS. IEEE 802.11e standard offers QoS in two steps. Initially, a priority based effort service such as Diffserv is aided. Then parameterized QoS is aided to help the applications needing QoS for different type of flows. This is attained by improving the DCF and PCF modes in IEEE 802.11e, and then by offering a signalling technique for the QoS that are parameterized. MAC protocols like enhanced DCF (EDCF) and enhanced PCF (EPCF) are members of the IEEE 802.11e. However, these two protocols are combinedly called as Hybrid Coordinated Functions (HCF) [24].

3.4.2 Hybrid Coordination Function Scheme

For the high speed infrastructure WLAN, hybrid medium access mechanism is designed and is referred as hybrid coordination function. This technique unifies the benefits of the PCF and DCF modes. This mechanism aids the QoS needs such as PCF when using the CSMA channel access schemes like DCF. In this hybrid mechanism, the backoff timers are scheduled by the master station for each and every related client stations, then this information is transmitted to the respective client along with the frames. On receiving the information, the client station initiates the backoff process. The generic scheduling algorithm is utilized by the master station to assign random slots for the clients. To improve the throughput of the mechanism, piggybacking frame exchange scheme is used [25].

3.4.3 EDCF enhancement

The EDCF enhancement mechanism improves the network QoS by employing an ADB algorithm. This ADB algorithm administers the changes in CW depending on the packet age and lifetime. Small variation is needed in the estimation of CW to reduce the migration effect from IEEE 802.11e EDCF mode, as well as to provide backward compatibility to the original IEEE 802.11DCF mode. The ADB algorithm reduces the delay, jitter and drop rate involved in the RT packet transmission to a greater extent and also avoids starving of the BE traffic [26].

3.4.4 EDCF and polling based Hybrid Coordination Function

In the EDCF and polling based Hybrid Coordination Function, there are two access mechanisms: contention based coordination mechanism referred as the Enhanced Distributed Coordination Function (EDCF), and a polling dependent mechanism that is operated by the Hybrid Coordinator (HC), and positioned at the Access Point (AP) [27].

3.4.5 Prioritized Adaptive EDCF

A Prioritized Adaptive EDCF scheme which is based on TCP is proposed to improve the existing IEEE 802.11e EDCF mechanism. It assigns the highest priority to TCP control packets and adjusts the corresponding MAC parameters. It also investigates the performance of a joint MAC/TCP scheme to enhance the performance of low priority TCP-based applications in the presence of high priority UDP-based traffic [30].

IV. INFERENCE OF THE STUDY

The survey is summarized in the following table.

Category	Technique Name	Performance Metrics	Advantages	Drawbacks
Scheduling Technique	Wireless Timed Token Protocol	Variable Bit Rate (VBR) and constant bit rate (CBR)	Lower delay, efficient polling strategy and bandwidth sharing	When traffic load is high, delay increases.
	Token based scheduling	Traffic Prioritization	Ensures fairness	Loss of radio resource utilization
	Feedback based controlled Scheduling	Bandwidth	Reduced Delay	Complex computation

	Enhanced Fair Scheduling	Bandwidth and Throughput	Balanced bandwidth allocation, higher throughput and lower delay	Priority is based on length and weight ratio.
	Adaptive Fair Distributed Scheduling	Time allotment for channel utilization	Works efficiently without any centralized coordinator	A node can function as a access point only if it connected to the backbone, else not possible.
	Packet Scheduling	Packet count	Works efficiently even in noisy environment	QoE estimation of multimedia transmission over IEEE 802.11e HCCA is not performed. Scheduling schemes for transmission of VBR traffic in a noisy environment has to be discussed.
	Immediate Dynamic TXOP HCCA (IDTH)	Delay	Deals with the variability of multimedia traffic and avoids waste of resources	traffics of different priorities are not considered
Admission Control	MAC QoS based admission control	Hop distance	Avoids unnecessary channel access	packet loss bursts due to mobility is not handled based on source coding techniques. Performance of multimedia traffic in mobile scenarios is not analyzed
	Collaborative Scheme	Traffic classification	Multimedia service with QoS is provided on end to end basis	Performance verification is not done
	Adaptive QoS admission control	Packet count for every flow	Dynamic adjustment of the traffic flow	the major challenge is how to trade off between QoS, admission rate/blocking probability, and network utilization. For system-wide QoS, it is not possible to know how to ensure end-to-end QoS, how to optimally map the QoS requirements between different

				network layers, how to map the QoS from application into the channel access parameters, and how to dynamically adjust the QoS on upper layers while underlying network condition changes.
	EDCA and HCCA based admission control	Data Rate	Handles different traffic loads effectively	Not able to effectively select TXOPs to tradeoff between flow QoS and network utilization. Another challenge is how to tradeoff between HCCA and EDCA in a mixed HCCA and EDCA scenario.
	QAP based admission control	Data Rate	Traffic loads can be handled efficiently	With the increase in the real time traffic, there are chances of packet drop
	Call admission and Rate Control Techniques	Throughput, channel utilization and delay	Avoids starvation of best effort traffic	Is based on old EDCA scheduler – not on HCCA
Channel Access Provisioning Technique	Weighted Fair Uplink/Downlink access provisioning	Uplink and downlink data ratio and data prioritization	Fair and efficient resource allocation	delayed TCP ACK mechanism is used
	Asymmetric access point based channel access	Packet rate	Lower delay, Higher throughput, fairness	for different frame sizes and multiple bit Rates, the AAP performance cannot be analysed
	Channel Access Throttling	Channel Access and Access Category	Higher channel capacity	This technique can be performed only off the shell hardware
Enhancing IEEE 802.11e MAC protocol	EDCA and HCCA based IEEE 802.11e enhancement	Priority based effort service	Works efficiently in both infrastructure based and infra structureless network	HCCA and EDCA is not compared in order to determine the best method to attain QoS

	Hybrid Coordination Function	Channel Access	Increased Throughput	If the master station fails, then this technique will not work efficiently
	EDCF enhancement	Contention window	Reduces delay, jitter and drop rate	Some changes are needed to estimation of the contention window (CW).
	EDCF and polling based hybrid coordination function	Data rate	Effective polling scheme even in adverse conditions	Periodic polling is not possible
	Adaptive TXOP allocation scheme	Throughput	Transmission opprotunities are effectively predicted and used in handling the network traffic	This scheme operation is not effective with nodes which belong to the background data access class with less traffic
	Prioritized Adaptive EDCF	Traffic efficiency, throughput and delay	Reduces the negative effects of service differentiation on TCP performance	Based on old EDCF mechanism – not considering HCCA scheduler

V. Conclusion

In this paper, the IEEE 802.11e protocol is studied with respect to the QoS enhancement perspective. A wide range of QoS enhancement techniques in IEEE 802.11e such as scheduling technique, admission control technique, channel access processing technique and Enhancing IEEE 802.11e MAC protocol are analyzed. The existing survey related to the proposed study is discussed. For each technique, we have discussed the properties, describe the operation, performance metrics, and list the advantages and limitations. This can be helpful in developing new techniques by understanding the existing techniques.

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