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Improved QoS in WLAN using IEEE 802.11e

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Abstract

In this paper, a detailed overview of the new attributes of a long term effective standard IEEE 802.11e to aid Quality of Service (QoS) with Wireless Local area Networks (WLANs) is presented. We address Medium Access Control (MAC) enhancements revealed in the present 802.11e draft standards by centering the problems with the legacy 802.11 standard. Cutting edge mechanisms for QoS assistance, specifically Enhanced Distributed Coordination Function (EDCF) and Hybrid Coordination Function (HCF), defined within the 802.11e drafts are usually evaluated. The effectiveness of new schemes is layed out via simulation outcomes.

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Keywords: EDCF; HCF; IEEE 802.11; MAC; QoS.

1. Introduction

The IEEE 802.11 for the wireless local area network (WLAN) standard focuses on the medium access control (MAC) and physical layer (PHY) for access point (AP)-based networks and ad-hoc networks. The main standard supported three PHY infrared (IR), frequency hopping spread spectrum (FHSS), and direct sequence spread spectrum (DSSS)[1–3]. The 802.11b extension of the standard supports DSSS in the 2. 4-GHz band with data rates of 1, 2, 5.5, and 11 Mbps. The last two bit rates are reached through complementary code keying (CCK)[4–7]. Extension 802.11a and g are for a high bit rate orthogonal frequency division multiplexing modulation (OFDM) PHY standard providing bit rates in the range of 6 to 54 Mbps in the 5-GHz and 2. 4-GHz band, respectively[2,3,5,6]. All the PHY have the same MAC layer, carrier sense multiple access/collision avoidance (CSMA/CA), of which enhancements are being finalized specifically for security and quality of service (QoS). The principles discussed with this paper are good standardization initiatives of Philips to enhance the QoS performance associated with WLANs. Such a network could open a number of opportunities for new multimedia media applications on mobile/portable items.

In the following paragraphs we explore the long term enhancements of the 802.11e standard as specified in the current draft[8]. Constraints of QoS support in the legacy 802.11 are layed out in the next section. We summarize the new mechanisms for QoS support being defined in 802.11e. A performance evaluation of the described mechanisms with the help of simulations is available, pursued by conclusions.

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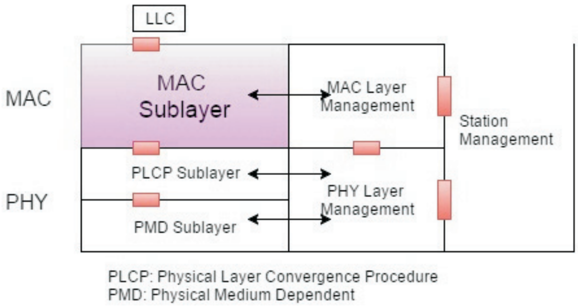

Fig. 1. IEEE 802.11 entities[2].

2. Basic IEEE 802.11

The standard, which is officially called "IEEE Standard for Wireless LAN Medium Access (MAC) and Physical Layer (PHY) Specifications," defines over-the-air protocols necessary to support networking in local areas. As with other IEEE 802-based standards (e.g. 802.3, and 802.5), the primary service of the 802.11 standard is to deliver MAC service data units (MSDUs) between peer logical link controls (LLCs). Typically, a radio card and AP provide functions of the 802.11 standard[1].

2.1 IEEE 802.11 logical architecture

A topology provides a means of explaining necessary physical components of a network, but the logical architecture defines the network's operation. The logical architecture of the 802.11 standard that applies to each station consists of a single MAC and one of multiple PHYs[1–5, 13–15]. The goal of the MAC layer is to provide access control functions (such as addressing, access coordination, frame check sequence generation and checking, and LLC PDU delimiting) for shared-medium PHYs in support of the LLC layer. The MAC layer performs the addressing and recognition of frames in support of the LLC. The 802.11 standard uses CSMA/CA, whereas standard Ethernet uses carrier sense multiple access with collision detection (CSMA/CD). It is very impractical to transmit and receive on the same radio channel at the same time due to the extreme ratio between the transmitted and received power. Therefore, an 802.11 wireless LAN only takes measures to avoid collisions, not detect them. In Fig. 1 IEEE 802.11 entities are given.

2.2 Medium access control layer

The 802.11 basic medium access behaviour allows interoperability between compatible PHYs through the use of the CSMA/CA protocol and then a random backoff time carrying out a busy medium condition. Additionally, all guided traffic uses instant positive acknowledgment (ACK frame), in which the sender plans a retransmission if no ACK is received. The 802.11 CSMA/CA protocol was designed to reduce the collision probability around multiple stations accessing the medium with the time limit at which collisions might probably occur. Collisions are usually to take place soon after the medium becomes free and just after busy medium conditions. Due to the fact multiple stations might have been waiting for the medium being accessible just as before. Therefore, a random back-off arrangement is needed to eliminate medium contention disputes. The 802.11 MAC also identifies the manner beacon frames is usually sent from the AP at regular intervals (like 100 ms) to enable stations to monitor the existence of the AP. The MAC also gives a set of management frames which permit a station to actively scan for other APs on any accessible channel. Influenced by these details the station would choose the best matched AP. In addition, the 802.11 MAC defines special functional behaviour for fragmentation of packets, medium reservation via request-to-send/clear-to-send (RTS/CTS) polling interaction, and point coordination (for time-bounded services)[1,2,7]. The MAC sublayer is responsible for the channel allocation procedures, protocol data unit (PDU) addressing, frame formatting, error checking, and fragmentation and reassembly.

Table 1. MAC Values in Microseconds for different PHYs.

PHY	SIFS	DIFS	Slot time	CW_{min}
802.11a	16	34	9	15
802.11b	10	50	20	31
802.11g	10	50	20	15

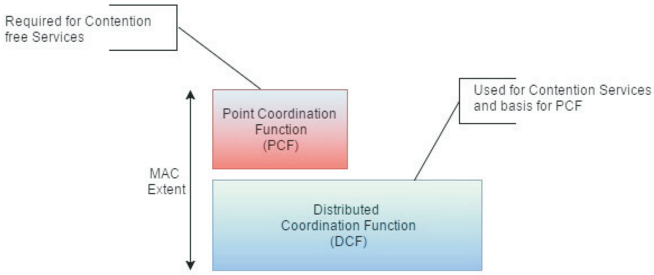

Fig. 2. MAC Architecture[1–4].

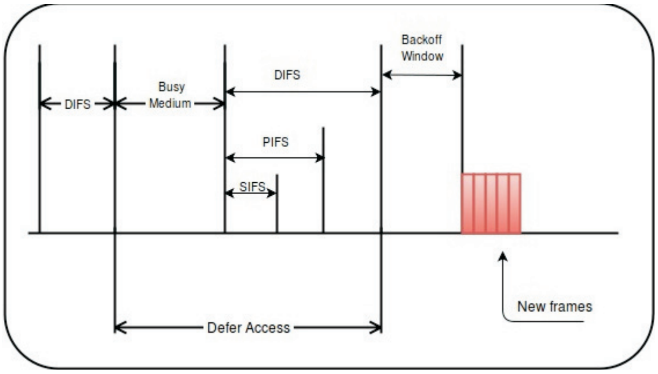

Fig. 3. Inter Frame Relationship[3].

2.3 Inter frame spacing

In Fig. 3 inter frame spacing (IFS) required for the original 802.11 MAC protocol are given while values for different IFS are given in Table 1.

SIFS = Short inter frame space = as in Table 1 dependent on PHY
PIFS = point coordination function (PCF) inter frame space = SIFS + slot time
DIFS = distributed coordination function (DCF) inter frame space = PIFS + slot time
the back-off timer is expressed in terms of number of time slots.

3. IEEE 802.11 MAC Protocol

The principal medium access scheme in IEEE 802.11 MAC is a distributed coordination function (DCF), a contention-based protocol that draws on a carrier sense Multiple-access/collision avoidance (CSMA/CA) protocol. Within the DCF, mobile terminals must contend for the shared wireless channel, and so, the medium access delay per each station (STA) shouldn't be bounded in heavy-traffic-load circumstances. Thereby, the DCF is useful in delivering just asynchronous data transmission using a best effort (BE) basis. As a way to support real-time traffic like voice and video, the point coordination function (PCF) scheme is advised being non-compulsory choice. Basically, the PCF draws on a centralized polling scheme which is a point coordinator (PC) surviving in an access point (AP)

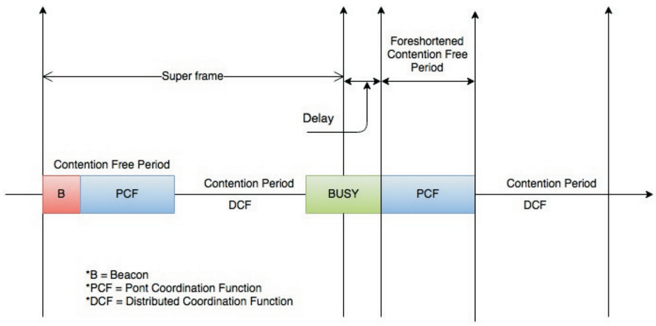

Fig. 4. Coexistence of PCF and DCF[4,8].

provides contention-free services to the associated stations in a polling list[2,3,8]. Recently, appreciable involvement with wireless networks supporting quality of service (QoS) has grown noticeably. The PCF is accessible in IEEE 802.11 available QoS however, has not still been implemented in reality because of several complex constraints and effectiveness poor attributes.

3.1 The Distributed Coordination Function (DCF)

The DCF will be the significant access method would always support asynchronous data transfer using a best effort basis. As soon as identified while using specification, all stations have to support the DCF. The DCF functions on their own with the ad-hoc network, as well as functions alone or coexists while using PCF within an infrastructure network. The MAC architecture is shown in Fig. 2, at which it truly is exhibited that DCF is situated immediately upon the physical layer and supports contention services. Contention services signify each station with an MSDU queued meant for transmission have to contend for usage of the channel and, the moment the MSDU is carried, need to recontend for usage of the channel for all succeeding frames. Contention services, improve fair usage of the channel for all stations[1,2,15–17]. The DCF draws on CSMA/CA. In IEEE 802.11, carrier sensing is carried out at both air interface, termed as the physical carrier sensing, and for the MAC sublayer, termed as virtual carrier sensing. Physical carrier sensing finds the presence of other IEEE 802. 11 WLAN users by analyzing all noticed packets, and finds action in the channel via relative signal strength from other sources.

A source station executes virtual carrier sensing by delivering MPDU extent information in the header of request to send (RTS), clear to send (CTS), and data frames. A MPDU is an over-all data units which can be directed through the MAC sublayer to the physical layer. The MPDU comprises header information, payload, and a 32-bit CRC. The extent field means the sum of time (in microseconds) as soon as the end of the present frame the channel can be useful to complete the successful transmission of the data or management frame.

Stations within the BSS as an information with the extent field to regulate their network allocation vector (NAV), which implies the sum of time that have to elapse prior to when current transmission session is complete and the channel can be sampled again for idle status. The channel is known busy if either the physical or virtual carrier sensing mechanisms seems to indicate the channel is busy.

3.2 The Point Coordination Function (PCF)

This PCF will be an elective capability which can be connection-oriented and offers contention-free (CF) frame transfer. The PCF will depend on the point coordinator (PC) to execute polling, allowing polled stations to transmit free of contending with the channel[3,7]. The operation of the PC is carried out through the AP within each BSS. Stations within the BSS that can handle operating in the CF period (CFP) are known as CF-aware stations. The way polling tables usually are managed and the polling sequence is set can be eventually left to the implementor.

Generally in case the PCF can be accomplished, a CFP throughout the PCF and then a CP throughout the DCF swap eventually. A CFP and then a CP kind a super frame. The AP in which the point coordinator (PC) is usually positioned

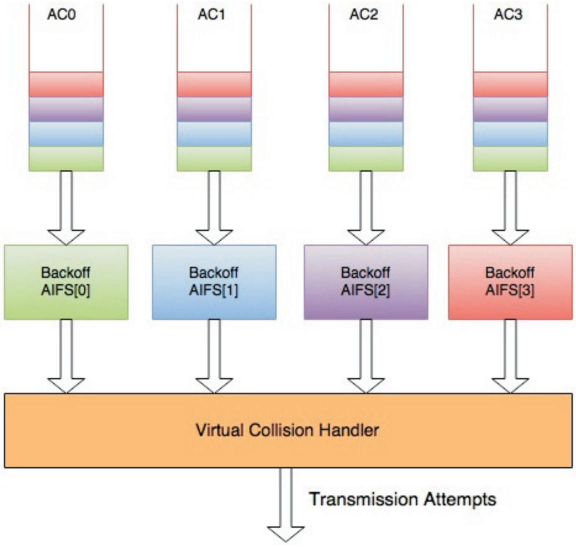

Fig. 5. Virtual Contention with in a Station[1–4].

senses a medium idle for the PIFS interval, thereafter transmits a beacon frame to trigger a CFP (i.e., to trigger a super frame). After a SIFS time, the PC communicates a poll frame to the station to demand to transmit a frame. The poll frame might or even might not include data to that station[3,6]. The coexistence of DCF and PCF is shown in Fig. 4. When accepting a poll frame through the PC, the station by having a frame to transmit could transmit a frame after a SIFS time. As soon as destination station receives the frame, an ACK is arrived at the source station after a SIFS time. The PC waits a PIFS interval subsequent ACK frame prior to when polling another station or terminating the CFP by sending a CF-End frame. If the PC receives no response from the polled station for a PIFS interval, the PC can poll the next station or terminate the CFP by sending a CF-End frame. The PCF is unable to provide good QoS support since it poor an admission function to regulate channel access from stations. Therefore, when the traffic load is exorbitant, all existing traffic could possibly degraded.

4. IEEE 802.11e MAC

A few high-layer applications like data, video, and audio need several prerequisites in bandwidth, delay, jitter, and packet loss. Nevertheless, with the DCF mechanism of IEEE 802.11, each of the stations and data flows hold the equal priority to access the medium. There is no difference mechanism to aid the transmission associated with data streams with several QoS prerequisites. To aid applications with QoS above 802.11 WLANs, the IEEE 802.11 working group is currently developing a standard identified as IEEE 802.11e, which expands the original 802.11 MAC to aid applications with QoS prerequisites. The potential IEEE 802.11e standard develops an alternative medium access mechanism, HCF, which often collectively is accessible with basic DCF/PCF meant for backward compatibility. HCF offers each of this contention-based and controlled contention-free channel access methods available as one channel access protocol. The HCF unit's functions from the DCF and PCF with quite a few improved QoS-specific mechanisms and frame subtypes providing a traditional set of frame exchange sequences being useful for QoS transfers all through either CP or CFP.

The HCF implements a contention-based channel access method, named the enhanced DCF (EDCF) that functions jointly with a controlled channel access mechanism influenced by a polling mechanism. This EDCF in 802.11e will be the contention based medium access method for HCF. QoS support is noticed while using benefits of traffic categories (TCs). This EDCF gives differentiated distributed access to the wireless medium meant for eight priorities of stations. EDCF channel access specifies the access category (AC) mechanism to provide assistance with

Table 2. Access Category Mapping IEEE 802.11e.

User Priority	Access Category	Traffic Type
1	0 (BK)	Background (BK)
2	0 (BK)	Spare or Standard
0	1 (BE)	Best Effort (BE)
3	1 (BE)	Excellent Effort (EE)
4	2 (VI/A_VI)	Controlled Load or Streaming Multimedia (CL)
5	2 (VI)	"Video" ¡ 100ms latency and jitter or Interactive Multimedia (VI)
6	3 (VO)	"Voice" ¡ 10ms latency and jitter Interactive Voice (VO)
7	3 (VO/A_VO)	Network Control or Reserved (NC)

Table 3. Typical QoS Parameters.

AC	$CW_{\min}$	$CW_{\max}$	AIFS
0	$CW_{\min}$	$CW_{\max}$	2
1	$CW_{\min}$	$CW_{\max}$	1
2	$(CW_{\min}+1)/2-1$	$CW_{\min}$	1
3	$(CW_{\min}+1)/4-1$	$(CW_{\min}+1)/2-1$	1

the priorities for the stations. Each station often has close to four ACs to aid eight user priorities (UPs). One or two UPs are issued to a single AC. A station accesses the medium while using AC of the frame being transmitted. This mapping coming from priorities to ACs is classified in Table 2[6]. Every single AC will be an improved version of the DCF. It contends for transmission opportunities (TXOPs) choosing a pair of EDCF channel access parameters. TXOP is a time span if a specified station offers the right to resume transmissions upon the wireless medium. The AC with higher priority is issued a quicker CW in order to guarantee that, usually, a higher-priority AC will transmit in advance of lower-priority ones. This is done by setting the CW limits CWmin[AC] and CWmax[AC], from where CW[AC] is calculated, to several values for several ACs. For even more difference, several interframe space (IFS) is unveiled based on ACs. In lieu of DIFS, an arbitration IFS (AIFS) is needed. This AIFS is a minimum DIFS, which will be increased independently per AC. Akin to DCF, if the medium is sensed to remain idle with the EDCF mechanism, a transmission will start immediately. If not, the station defers before end of active transmission over the WM. When deferral, the station waits for a period of AIFS (AC) to start a backoff procedure. The backoff span is actually a random number tempted with the span [1, CW (AC) + 1].

Each AC just a one station acts being a virtual station. It contends for usage of the wireless medium and on his own starts its backoff time when sensing the medium is idle to get minimum AIFS. Collision between ACs inside of a single station are managed inside station so that the data frames coming from higher-valued AC obtain the TXOP, and the data frames from lower-valued colliding ACs work as when they had a external collision over the wireless medium. The timing relationship for an EDCF is shown in Fig. 6[4].

The prioritized medium access of the EDCF in 802.11e is concluded by setting various CWs and various AIFS to support various ACs. Data units can be delivered within many backoff scenarios inside one station. Each backoff scenario is parameterized along with TC-specific parameters. The standard values of CW limits and AIFSs for several ACs in the QoS constraints set is shown in Table 3. A model of the virtual contention is shown in Fig. 5[6]. It illustrates a mapping with frame category or priority to ACs, the four queues, and four independent channel access functions, one per each queue. The HCF controlled channel access mechanism is able access to the WM with an HC who has better medium access priority than the EDCF. This permits it to transfer data from itself and allot TXOPs to stations. A HC is a kind of PC, but works at several rules than a PC. HC traffic delivery and TXOP allocation can be reserved during both CFP and CP. The HCF transfer protocol draws on a polling scheme controlled by an HC using at AP. The HC acquires control with the WM since needed supply QoS traffic to stations and concern QoS (+) CF-polls to stations by priming a lower time around transmissions than the stations with an EDCF or a DCF. The extent values applied to QoS frame exchange sequences retain a medium for a slot time period extended than the end of the sequence to let extension on the network allocation vector (NAV)-protected CF sends by concatenation with contention-free bursts.

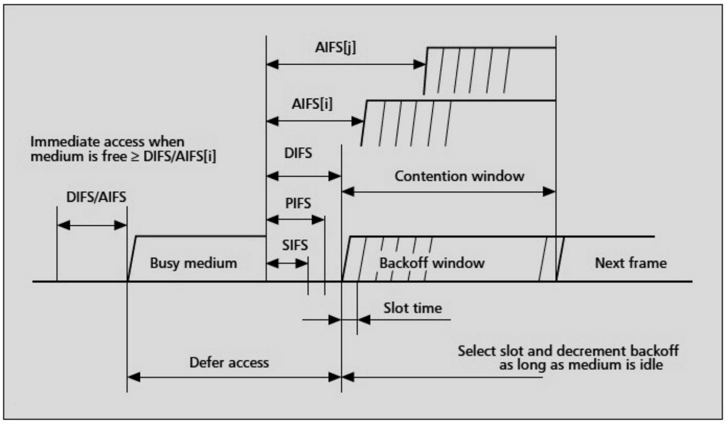

Fig. 6. EDCF Timing Diagram[4].

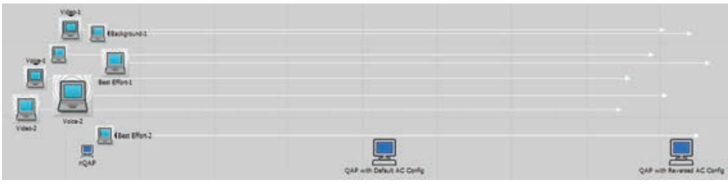

Fig. 7. OPNET Modeller [Academic Edition 17.5] IEEE 802.11e Study.

This approach increased wireless medium reservation may help an HC to help induce a succeeding TXOP using lower probability of collision considering all stations it is necessary TXOP rack and the HC is not allowed to initiate contending till a DIFS span afterwards than the terminate of the prior transfer throughout the TXOP.

5. Configuration

The network consists of 3 APs. The first AP, AP of BSS-1, can be described as non-QAP i. e., this is the legacy AP it does not support QoS premises with the 802.11e protocol. The AP of BSS-2 supports 11e, therefore it is a QAP. The EDCA Parameter Set values which it functions for their operation and those it promotes to its member STAs for a medium contention are set with the values suggested in the 802.11e standard. AP of BSS-3 is also a QAP, but it uses and promotes a ”reversed” set of EDCA parameter values.

This means the standard suggested values for “Voice” access category (AC) are being used and offered for “Background” AC, and vice-versa. Similar “exchange” is also carried out between “Video” and “Best Effort” ACs. Overall, it reverses the relative priorities of the ACs such that Background AC can be treated as the highest priority in the BSS, whereas Voice AC will become the lowest priority AC.

6. Simulation Outcomes

The WLAN end-to-end delay values measured by STAs Voice-1, Video-1 Best Effort-1 and Background-1 are compared. When all STAs belong to BSS-1, each reports similar end-to-end delays.

Although they will generate traffic of various QoS classes, here is the predicted result since AP they’re just plugged into is a legacy AP that does not assistance 11e QoS facilities.

As a result, the mobile STAs, even if they are QSTAs, simply cannot use their EDCA algorithm and its prioritized parameters to contend for the medium. Instead, they will operate the legacy DCF method to send traffic on their

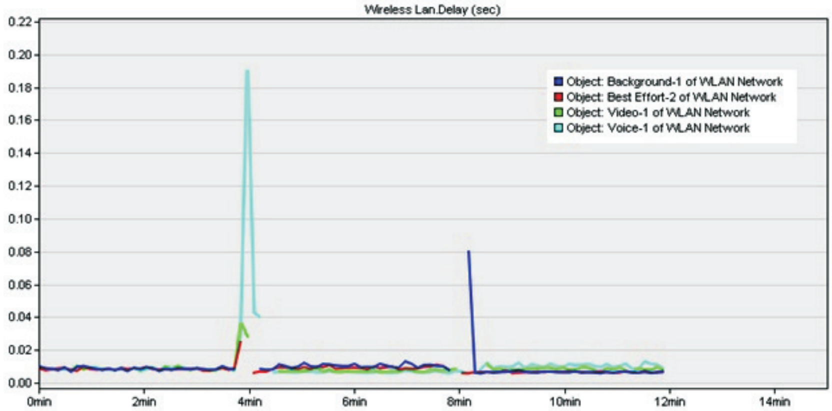

Fig. 8. WLAN Delay.

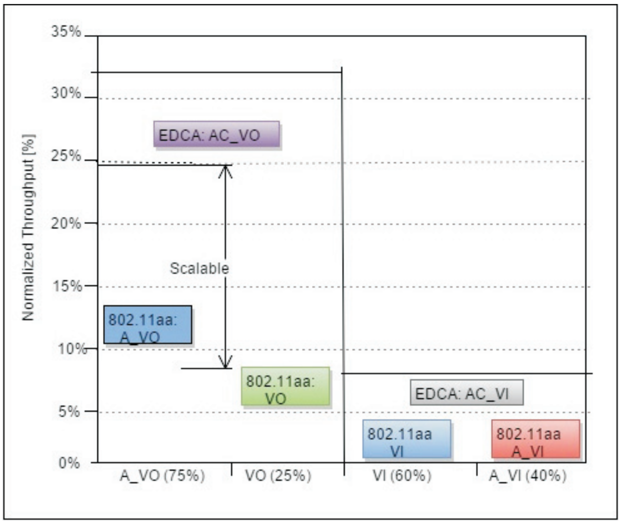

Fig. 9. WLAN AP Connectivity (intra access category).

associates using a legacy AP. Thus, virtually no prioritization is needed over the contention, generating every single STA experience similar delay values inspite of their various application traffic QoS (ToS) class.

When the mobile STAs roam with BSS-1 to BSS-2, they can be now make use of EDCA to contend for the medium since their current AP is often a QAP. Prioritized solution for the higher-layer traffic straight away impacts on the measured delay values.

At this point Voice-1 records the lowest delay values, whereas Background-1 records the highest values. Delay values associated with Video traffic are a bit worse than Voice traffic, but superior to Best Effort traffic, and Best Effort delays are superior to Background delays. Whenever STAs eventually proceed to BSS-3 a prioritization is “upside down” evidently with the configuration with QAP with BSS-3. Now Voice STAs feel the optimum delay values, whereas Background STAs observe the best or lowest values.

For instance, the consequence of global Video AC throughput figure is shown above with the scenario. Note that Video AC reports throughput only starting around 250 seconds in the simulation; this means that, only after the mobile STAs move to BSS-2. This is certainly predicted since, stated above, when STAs will be in BSS-1, they benefit from

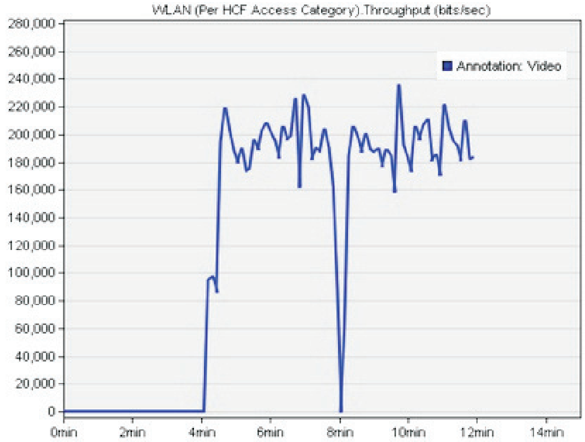

Fig. 10. WLAN (per HCF access category) Throughput (bits/sec).

pure DCF, since their AP fails to support 802. 11e. When acting as a nonQSTA and by using legacy DCF, QSTAs handle all higher layer traffic along with all traffic received from the medium as Best Effort traffic.

7. Conclusions and Future Scope

From this report, an 802.11e model developed with the OPNET Modeler has been presented. QoS of the model were implemented, choosing the concept of varying levels of services for different traffic types, i.e. voice, video and data. We defined four Access Categories, all which often supports a unique priority to access the radio channel. The QoS station has been modelled using a priority queue and access mechanism enhanced with the existing 802.11 model. Simulation outcomes show the validity about this type in addition to illustrate its fidelity and flexibility with the study of IEEE 802.11e QoS mechanisms.

A couple changes to IEEE 802.11 have recently been published 802.11aa and 802.11ae. Each of those improve Quality of Service (QoS) provisioning in Wi-Fi networks by providing support for multicast transmission, improved audio video streaming, coping with inter-network interference, and better prioritization of management frames.

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