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Real-Time HCCA scheduler and MAC Protocol for IEEE 802.11e WLANs: A Review

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Abstract: The IEEE 802.11 standard for wireless networks has been recently enhanced with the IEEE 802.11e amendment which introduces Quality of Service support. It provides differentiation mechanisms at the Medium Access Control layer, using two additional access functions: the Enhanced Distributed Channel Access (EDCA) function and the HCF Controlled Channel Access (HCCA) function. Only the HCCA mechanism is suitable for serving traffic streams with real-time requirements such as multimedia applications and Voice Over IP. The IEEE 802.11e standard does not specify a mandatory HCCA scheduling algorithm, but it offers a reference scheduler as the guideline in the resources scheduling design. In this paper we analyze four HCCA alternative schedulers to the reference one. They offer real-time guarantees proposing different solutions to the request of QoS and real-time support expressed by the increasing diffusion of multimedia applications. Real-Time HCCA (RTH), devised to support Quality of Service (QoS) at the flow level in an IEEE 802.11e network using the Hybrid Coordinator Function (HCF) Controlled Channel Access (HCCA) function. RTH separates online activities which take place at the frame transmission timescale, from offline activities which take place at the flow lifetime timescale. On the other hand, online scheduling is enforced simply by reading the pre-computed schedule, at little or no computational cost. RTH performance is assessed in terms of the admission control limit and of the amount of channel capacity that is left for contention-based access.

Keywords: Wireless Networks, Quality of Services, HCCA algorithm, IEEE 802.11e network.

I. INTRODUCTION

In wireless communications the Quality of Service and real-time guarantees provisioning are important issues due to the diffusion of mobile devices which support multimedia applications such as Voice over IP (VoIP), multimedia video, and videoconferencing. Furthermore, Constant Bit Rate (CBR) and Variable Bit Rate (VBR) traffic with different requirements need differentiated QoS levels with real-time guarantees [1].

On the other hand the space and time-varying characteristics of the wireless channel affect the network performance in terms of Signal to Interference plus Noise Ratio (SINR) and Bit Error Rate (BER). Thus it is not possible to assure hard QoS constraints in terms of exact values of network and application parameters including delay, delay jitter, packet loss ratio, and throughput. However the characteristics of multimedia applications allow us to consider soft requirements expressed by admitted intervals for the parameters' values. In fact, for multimedia applications, missing deadlines implies only a degradation of the received QoS and not catastrophic events. Therefore we can consider soft-real time constraints with the exception that we cannot employ the classical methodologies used in static real-time systems because they cannot handle the dynamic characteristics of both the wireless medium and the multimedia applications [2].

Even if IEEE 802.11 is the recognized standard for Wireless Local Area Networks (WLAN), it was designed to provide only best effort service. Recently it has been enhanced with the amendment IEEE 802.11e in order to include the QoS guarantees. The recent standard has introduced a differentiation mechanism at the Medium Access Control (MAC) layer, using two additional access functions: the Enhanced Distributed Channel Access (EDCA) function and the Hybrid Controlled Channel Access (HCCA) function. The EDCA function is based on a distributed control and enables prioritized channel access while the latter requires centralized scheduling and allows the applications to negotiate parameterized service guarantees. In particular, only HCCA mechanism is suitable for respecting real-time constraints. However the IEEE 802.11e standard does not specify a mandatory HCCA scheduling algorithm, while it offers a reference scheduler that is compatible with the use of link adaptation and that respects a minimum set of performance requirements. In particular it assigns a fixed transmission opportunity to all the managed flows, every a constant common period. Several studies have evaluated the new standard through analytical techniques and simulation and they had demonstrated that it improves the QoS support more specifically for CBR traffic whereas it displays its limits for VBR traffic, since it assigns fixed transmission parameters and it is not suitable for following the variability of this typology of traffic. Based on these considerations, several works have suggested alternative scheduling algorithms to the reference one, in order to improve its QoS provisioning for VBR traffic, but they do not consider specifically the real-time constraints [3]

II. LITERATURE SURVEY

Aqsa Malik et al., 2014 [4] defined aside from mobile phone system, IEEE 802.11- based wireless local area networks (WLANs) represent the most generally sent wireless networking technology. With the migration of basic applications onto information networks, and the emergence of multimedia applications, for example digital audio/video and multimedia games, the success of IEEE 802.11 depends critically on its ability to provide quality of service (QoS). A lot of research has focused on equipping IEEE 802.11 WLANs with features to support QoS. In this survey, they provide an overview of these techniques. They talk about the QoS characteristic incorporated by the IEEE 802.11 standard at both PHY and media access control (MAC) layers, as well as other higher-layer proposal. They also focus on how the new architectural developments of Software Defined Networking (SDN) and cloud networking can be used to facilitate QoS provisioning in IEEE 802.11-based networks.

Gabriele Cecchetti et al., 2012 [5] explained a IEEE 802.11e HCCA reference scheduler guarantees Quality of Service only for Constant Bit Rate traffic streams, whereas its assignment of scheduling parameters (transmission time TXOP and polling period) is too rigid to serve Variable Bit Rate (VBR) traffic. This survey presents a new scheduling algorithm, Dynamic TXOP HCCA (DTH). Its scheduling scheme, integrated with the centralized scheduler, uses both a statistical estimation of needed transmission duration and a bandwidth reclaiming mechanism with the expect of improving the resource management and giving an instantaneous dynamic Transmission Opportunity (TXOP), tailored\ to multimedia applications with variable bit rate. Performance evaluation through simulation, confirmed by the scheduling analysis, shows that this suitable to reduce the transmission queues length. This positively impacts on the delay and on packets drop rate experienced by VBR traffic streams.

TIMO A. WEISS et al., 2004 [6] presented that the article describes the technical challenges that have to be met when implementing the interesting new technology of spectrum pooling. This notion represents the coexistence of two mobile radio systems within the same frequency range. It enables the resulting use of previously licensed frequency bands as aimed at by numerous regulatory authorities worldwide. The goal of spectrum pooling is to enhance spectral efficiency by overlaying a new mobile radio system on an existing one without requiring any changes to the actual licensed system.

Deyun Gao et al., 2005 [7] described that the although IEEE 802.11 based wireless local area networks have become more and more popular due to low cost and easy deployment, they can only provide best effort services and do not have quality of service supports for multimedia applications. A new normal, IEEE 802.11e, has been probable, which introduce a supposed hybrid coordination function containing two medium access mechanisms: contention-based channel access and controlled channel access. They first give a brief tutorial on the various MAC-layer QoS mechanisms provided by 802.11e. They show that the 802.11e standard provides a very powerful platform for QoS supports in WLANs. Then they provide an extensive survey of current advances in admission control algorithms/protocols in IEEE 802.11e WLANs. They survey covers the research work in admission control for both EDCA and HCCA. They show that the new MAC-layer QoS schemes and parameters provided in EDCA and HCCA can be well utilized to fulfill the requirements of admission control so that QoS for multimedia applications can be provided in WLANs. Finally, they provide a synopsis of suggest of access control in EDCA and HCCA, and tip absent the remaining challenges.

L.W. Lim et al., 2004 [8] introduced in the application of IEEE 802.11e to the delivery of high bandwidth multi-media streams. The structural design for a QoS enabled MAC was described the length of with an efficient scheduling algorithm, which when deployed at the AP was able to serve QoS sensitive streams, while making efficient apply of the channel bandwidth. The 802.11e MAC is simulated using OPNET and the performance of both the EDCA and the HCCA channel access mechanisms was studied under various scenarios.

Vaishali D. Khairnar et al., 2013[9] discussed the traffic security application by means of vehicle-to-vehicle (V2V) communication is an emerging and promising area within the ITS environment. Several of these applications require real-time communication with high reliability. To meet a real-time deadline, timely and predictable way in to the channel is paramount. The medium contact techniques utilize in 802.11p, CSMA with collision avoidance, does not guarantee channel access previous to a finite deadline. The recognized property of CSMA is undesirable for dangerous communications scenarios. The reproduction results reveal that a specific vehicle is forced to drop over 80% of its packets because no channel access was possible before the next message was generated. To resolve that issue, they propose to use STDMA for real-time data traffic between vehicles. The real-time properties of STDMA are investigated by funds of the main road road reproduction scenario, with shows potential results.

Robson Costa et al., 2015 [7] explained that the IEEE 802.11 standard has been evolving over the past decade, introducing a set of new mechanisms at the MAC layer to improve the Quality of Service (QoS) provided to the communication. Among such improvements, they highlight the evolution from earlier DCF and PCF, until more recent EDCA and HCCA MAC layer mechanisms. In this paper we perform a simulation assessment of these four MAC

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mechanisms, evaluating their ability to support real-time (RT) communication. More specifically, we assess their ability to handle RT traffic in open communication environments composed of RT and non-RT stations operating in the same frequency channel and coverage area. The target of this paper is to highlight and understand the limitations of each mechanism when supporting RT communication. We show that for most of the situations, including less demanding scenarios, these mechanisms are not adequate to support RT traffic.

Qiang Zhou et al., 2016 [10] surveyed expect to utilize WLAN protocol to maintain the transmission of hard-real-time (HRT) traffic stream (TS) in safety serious real time system (SCRTS). Firstly, this survey analyzes the reference scheduling mechanism for IEEE 802.11e to guarantee Quality of Service (QoS) and talk about the drawback of the sample preparation algorithm for IEEE 802.11e Hybrid Coordination Function (HCF) controlled channel way in (HCCA) mechanism under the background of HRT application. And then, this survey advances an improved scheduling algorithm for HRT traffic stream which sets up the messages HRT attribute and adjust the transmission opportunity dynamically, aiming to guarantee HRT messages QoS. At least, the improved algorithm is implemented based on NS2 and the simulation result shows the optimized algorithm can recover the HRT traffic QoS effectively.

Table I. illustrates such mechanisms adopted by some algorithms. The algorithms named in the table using italic font will be described more accurately and compared.

Table. 1 Scheduling mechanisms

Scheduling mechanisms	**Algorithms**
Queue Length estimation	*FHCF, ARROW*
Feedback based mechanism	*FBDS*
Timed token	*WTTP*
Deadline- based scheduling	*SETT-EDD, RTH, WCBS*

One component of the packet delay is the queue delay, due to the lateness in the transmission queue delivering. A resources assignment tailored to the network traffic can reduce the waiting time experienced by the packets in the transmission queues. The algorithms can employ different types of information, depending on the use of a theoretical model or the actual values of the queues length. In the latter case, a better resource reservation is possible with respect to it being based on estimated queue length where the assigned TXOP could be major (waste time), minor (delayed packet) or equal (ideal case) with respect to the actual needed transmission time.

III. IEEE 802.11e HCCA (Hybrid CO-ordination Function)

The IEEE 802.11e Hybrid Coordination Function multiplexes between two medium access modes: the EDCA, which provides prioritized QoS to different traffic levels through the introduction of Access Categories (ACs), and the centralized HCCA. To ensure compatibility whit legacy devices, the standard allows the coexistence of Distributed Coordinator Function (DCF) and Point Coordination Function (PCF) with EDCA and HCCA. Because this paper is about schedulers for the latter mechanism we describe more in detail the HCCA function. HCCA provides a QoS-aware Hybrid Coordinator (HC), usually located at the QoS Access Point (QAP) in infrastructured WLANs, which provides polled access to the wireless medium. In order to be included in the polling list of the HC, a QoS Station (QSTA) must send a QoS reservation request to the QAP for each Traffic Stream(TS), using the special QoS management frame, Add traffic Stream, which contains the Traffic Specification (TSPEC). TSPEC includes parameters as mean data rate (Ri), nominal Service Data Unit size (Li), minimum PHY rate (Γi), Delay bound (Di) and Maximum Service Interval (MSI). HC aggregates QSTA TSPECs to determine the values of transmission parameters: Service Interval (SI) and Transmission Opportunity (TXOP). SI is the time duration between successive polls for the node and it is a submultiple of the 802.11e beacon interval duration. TXOP is the transmission duration of each node based on the mean application data rates of its requested flows. Before the calculation of the latter parameters, QAP has to verify if the admission of each TS does not compromise the service guarantees of the already admitted TSs and, if the specified TS is accepted, QAP sends a positive acknowledgement which contains also the service start time that indicates the time from when the QSTA is allowed to transmit frames relative to considered TS [11].

IV. IEEE 802.11e and QoS support

In this section, we set out the necessary background to the paper. First, we describe the enhancements of 802.11e that are related to the support of QoS using HCCA, as well as introducing some notations that will be used throughout this paper. We then review the related work on real-time scheduling in HCCA [12].

IEEE 802.11e MAC protocol

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As already mentioned, HCCA is a centralized access mechanism controlled by the HC, which resides in the QoS-Access Point (QAP). Each QoS enabled 802.11e station (QSTA) may establish up to eight HCCA Traffic Streams (TS). TSs are guaranteed a parameterized QoS access to the medium, and they can be either uni-directional (i.e., uplink or downlink), or bi-directional. In all cases, TSs are initiated and terminated only by QSTAs. However, the QAP performs an admission control procedure to ensure that the admission of a new TS does not violate the service guarantees of the already admitted TSs. The QAP can take control of the medium whenever it needs to allocate transmission opportunities (TXOPs) to TSs. It does so by accessing the medium with a higher priority than QSTAs. However that the QAP is not allowed to interrupt ongoing transmissions. During TXOPs, the medium is accessed by only one QSTA. More specifically, a downlink TXOP consists of a burst of QoS Data (data, for short) frames transmitted from the QAP to a QSTA. On the other hand, an uplink TXOP is initiated when the QAP polls a QSTA, which takes control of the medium for a time interval smaller than or equal to the TXOP duration limit specified in the QoS CF-Poll (poll, for short) message. If the TS of a polled QSTA does not have data to transmit, or if the head-of-line packet does not fit into the remaining TXOP duration, the QSTA sends a QoS CF-Null (null, for short) frame to the QAP. If the polled QSTA does not use up the TXOP entirely, then the QAP has two options:

(i) Take back control of the medium, by immediately starting a new TXOP, or
(ii) Resume the contention based access to the medium.

A sample HCCA frame exchange sequence is illustrated in Fig. 1[13]

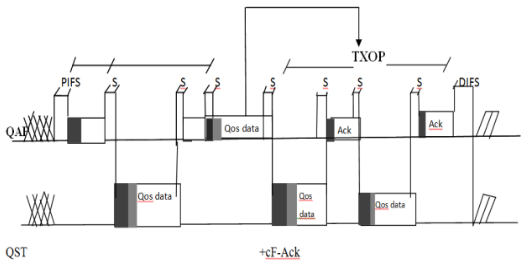

Fig 1. Sample HCCA frame Exchange Sequence

The time spent in polling QSTAs can be accounted for as a MAC overhead, which is added to the overhead due to direct acknowledgment of data frames. However, such overhead can be reduced by combining multiple control messages and/or piggybacking them on data frames. If the optional piggybacking feature is supported, the QAP may piggyback an acknowledgment and/or a poll on the ongoing data frame, as long as the control messages and the data frame are addressed to the same recipient.

V. Real-Time HCCA

The HCCA is an augmentation of the Point Coordination Capacity (PCF) convention. HCCA controls the WLAN through a module called Crossover Organizer (HC). Unequivocal access is given to the ongoing streams by HCCA amid the Conflict Time frame (CP). HCCA requires a brought together QoS-mindful organizer, called HC, which has a higher need than ordinary QoS-mindful stations (QSTAs) in picking up channel control. HC can pick up control of the channel in the wake of detecting the medium sit still for a PCF between outline space that is shorter than DCF between outline space received by QSTAs. Subsequent to picking up control of the transmission medium, HC surveys QSTAs as per its surveying list. Keeping in mind the end goal to be incorporated into HC's surveying list, a QSTA needs to consult with HC by sending the include activity stream outline. In this casing, the QSTA portrays the activity qualities and the QoS necessities in the movement particular (TSPEC) field. In light of the movement qualities and the QoS necessities, HC computes the booked administration interim (SI) and transmission opportunity (TXOP) length for each conceded stream. After getting a survey, the surveyed QSTA either reacts with QoS-information on the off chance that it has bundles to send or a QoS-invalid casing generally. At the point when the TXOP span of some QSTA closes, HC picks up the control of channel again and either sends a QoS-survey to the following station on its surveying rundown or discharges the medium if there is no more QSTA to be surveyed.

Scheduling Algorithm in HCCA [14]

The mechanism of HCCA utilizes the central control point (Hybrid Coordinator, HC) to control the access of wireless media. When joining the flow, the QSTA will send out an ADDTS request for the HC. Then the HC will be on the TSPEC field of the ADDTS request. The Sample Schedule will start the Controlled Access Phase (CAP) in one regular cycle by its length in the IEEE 802.11e standard. The length of this cycle is called the Service Interval (SI). The procedure begins from the calculation of the SI.

In HCCA, QoS-capable AP (QAP) sends CF-Poll frame to QoS-capable STA (QSTA) to inquire whether there is data to send in the inquiry mechanism of HCCA. Besides, data packet queue is sorted based on the requirements of communication service stream of every station. In every polling process, TXOP is assigned to every QSTA, indicating the data packet transmission start time and the longest duration. HCCA TXOP is calculated according to the traffic specification parameter of every QSTA data. Then, HCCA TXOP is transmitted along with CF-Poll frame to each QSTA.

Reference Scheduler

The reference scheduler proposed by the IEEE 802.11e standard suggests how to compute the main protocol parameters, SI and TXOP, suitable to meet the requirements globally expressed by each QSTA. Different values for each specific QSTA are computed only for TXOP, whereas SI is computed as a unique value for all non-AP QSTAs with admitted streams.

Drawback of HCCA algorithm

There are a few downsides concerning the operation of HCCA. Since the scheduler considers settled TXOPs, it can't proficiently bolster VBR movement, while this kind of activity is created by various applications. Moreover, the utilization of surveying bundles and affirmations are data transfer capacity expensive. Additionally, it neglects to proficiently separate the TSs, since it doesn't utilize continuous movement needs. Ultimately, no vitality preservation is bolstered. Along these lines, it turns out to be certain that a more proficient convention could be presumably utilized.

VI. CONCLUSION

In this conclusion, it surveyed the HCCA algorithm and Reliability Factor used with the scheduling process. In order to evaluate how suitable they are to support traffic streams requiring soft real-time guarantees, we have analyzed their characteristics. In particular the admission control phase has been tested under different scenarios both analytically and through simulation. Then the efficient use of the medium has been studied considering the null rate and the polling interval produced with mixed traffic streams. This mechanism enhances the inefficient HCCA polling scheme, by means of a group sequence communication based on virtual token passing procedure among RT stations. This technique guarantees a smaller polling overhead, when compared to the IEEE 802.11e original scheme. This technique is particularly adequate to typical industrial communication scenarios, where Stations transfer multiple small-sized packets at periodic intervals.

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