UNIVERSITI PUTRA MALAYSIA

ENHANCEMENTS ON HYBRID COORDINATION FUNCTION CONTROLLED CHANNEL ACCESS FOR VIDEO TRANSMISSION IN IEEE 802.11E NETWORK

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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March 2016

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The rapid advancement in wireless technologies and the reduced cost in electronic hardware has stimulated the vast deployment of Wireless Local Area Networks (WLANs) in public and residential places. Nowadays, a wide range of multimedia traffics emerge in WLANs with different Quality of Service (QoS) requirements. In order to support multimedia traffics with stringent requirements, IEEE 802.11e introduced HCF Controlled Channel Access (HCCA). In HCCA, Transmission Opportunity (TXOP) duration is allocated to the QoS-enabled Station (QSTA) based on the mean characteristics of its Traffic Stream (TS) described by a TS Specification (TSPEC). Although HCCA operates well for the Constant Bit Rate (CBR) traffics, it is inadequate for Variable Bit Rate (VBR) traffic, where the instantaneous sending rate and the packet size are usually different from its mean values. The aim of this research is to address the deficiency of HCCA in supporting VBR video transmission over wireless networks.

Accordingly, a novel polling scheme called Feasible Polling (F-Poll) is proposed to minimize the delay imposed by overpolling stations in the HCCA function. The actual arrival time of the next frame of the uplink TS is obtained and reported to the central scheduler called Hybrid Coordinator (HC). Upon the reception of the data frame at the HC, a decision will be made to poll the corresponding station in the next Service Interval (SI) or not to prevent stations that are not ready to transmit from receiving unnecessary polls. Consequently, the packet access delay and the channel utilization will be enhanced.

The TXOP in HCCA scheduler is allocated to the QSTA based on its TSPEC by estimating the amount of data expected to be transmitted by the QSTA during the service interval. Yet, this estimation is not accurate for VBR traffics. Thus, a novel TXOP assignment scheme is proposed which is referred to as Adaptive TXOP Scheme (ATXOP). In this scheme, the TXOP duration is adopted based on the feedback of the actual next frame size reported by QSTAs. So, an accurate TXOP is allocated to the station to ensure that the end-to-end delay is minimized without jeopardizing the channel bandwidth. To leverage the benefit of the ATXOP, a multi-polling scheme has been integrated and named Adaptive Multipolling TXOP Scheme (AMTXOP).

Moreover, a new approach incorporating the polling scheme and the TXOP assignment of HCCA scheduler has been presented called Adaptive Feedback-based HCCA Scheduler (AF-HCCA). The AF-HCCA accommodates to the video applications that show variability in both frame inter-arrival time and frame size, such as H.263 streams. The proposed scheme, accurately assigns TXOP duration time for each traffic stream which is just enough to send their data. Moreover, it only polls QSTAs when needed to minimize the delay and conserve the bandwidth channel.

The findings demonstrate that F-Poll is a promising scheme for supporting video streams with a different variability level of frame inter-arrival time while ATXOP scheme and its enhanced version, namely AMTXOP is beneficial for video streams that show variability in packet sizes such as H.264 streams. The integrated scheme shows further improvements for VBR video streams. The results show that F-Poll, ATXOP and AMTXOP schemes outperform the HCCA polling and TXOP assignment schemes in terms of the end-to-end delay and the channel bandwidth utilization while maintaining the system throughput. Moreover, the AF-HCCA shows superior improving in the packet end-to-end delay and remarkably minimize the polling overhead compared to not only the HCCA scheduler, but also to one of the recent enhancement of HCCA scheduler called Enhanced Earliest Due Date (EDD) scheduler.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENAMBAHBAIKAN FUNGSI PENYELARASAN CAMPURAN CAPAIAN SALURAN TERKAWAL UNTUK PENGHANTARAN VIDEO DALAM RANGKAIAN IEEE 802.11E

Oleh

MOHAMMED AHMED MOHAMMED AL-MAQRI

Mac 2016

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Kemajuan pesat dalam teknologi tanpa wayar dan pengurangan kos dalam perkakasan elektronik telah merangsang perlaksanaan Rangkaian Setempat Tanpa Wayar (WLAN) secara meluas di tempat-tempat awam dan rumah kediaman. Pada masa kini, pelbagai jenis trafik multimedia muncul dalam WLAN dengan keperluan kualiti perkhidmatan (Quality of Service QoS) yang berbeza. Dalam usaha untuk menyokong trafik multimedia yang datang dengan pelbagai keperluan yang ketat, protokol IEEE 802.11e memperkenalkan HCF Kawalan Akses Channel (HCCA). Dalam HCCA, tempoh bagi peluang penghantaran atau Transmission Opportunity (TXOP) diperuntukkan kepada Stesen QoS yang dibolehkan (QSTA) berdasarkan ciri-ciri min aliran trafik atau traffic stream (TS) seperti yang digambarkan oleh Spesifikasi TS (TSPEC). Walaupun HCCA beroperasi dengan baik bagi trafik kadar tetap (CBR), tetapi, ia tidak mencukupi untuk trafik kadar bit pembolehubah (VBR), di mana kadar penghantaran serta-merta dan saiz paket biasanya berbeza daripada nilai-nilai min. Oleh itu, tujuan kajian ini adalah untuk menangani kekurangan HCCA dalam menyokong transmisi video VBR melalui rangkaian tanpa wayar.

Sehubungan dengan itu, satu skim pengundian baru dipanggil Pengundian Boleh Laksana atau Feasible Polling (F-Poll) dicadangkan untuk mengurangkan keadaan lengah yang dikenakan oleh stesen pengundian yang berlebihan (overpolling) dalam kefungsian HCCA tersebut. Masa ketibaan sebenar untuk kerangka seterusnya bagi aliran trafik (TS) pautnaik atau TS uplink diperoleh dan dilaporkan kepada pusat penjadual , yang dipanggil Penyelaras Hibrid (HC). Selepas penerimaan kerangka data di HC, keputusan akan dibuat sama ada untuk mengundi stesen yang sepadan dalam selang perkhidmatan (Interval

Service/SI) seterusnya atau tidak, dengan tujuan mencegah stesen yang tidak bersedia untuk membuat penghantaran daripada menerima pengundian yang tidak perlu. Oleh itu, kelewatan Akses paket dan penggunaan saluran akan dipertingkatkan.

Peluang penghantaran (TXOP) dalam penjadual HCCA yang diperuntukkan kepada QSTA adalah berdasarkan TSPEC, dengan menganggarkan jumlah data yang dijangka dihantar oleh QSTA semasa tempoh perkhidmatan. Namun, anggaran ini adalah tidak tepat untuk trafik VBR. Maka, satu skim tugasan TXOP yang baru telah dicadangkan, disebut sebagai skim penjadualan mudah suai TXOP atau Adaptive TXOP scheme (ATXOP). Dalam skim ini, tempoh TXOP yang diguna pakai berdasarkan kepada maklum balas daripada saiz sebenar kerangka seterusnya yang dilaporkan oleh QSTAs. Dengan itu, TXOP yang tepat dapat diperuntukkan kepada stesen untuk memastikan bahawa keadaan lengah dari hujung ke hujung akhirnya dapat dikurangkan tanpa menjejaskan lebar jalur saluran. Bagi memanfaatkan manfaat ATXOP, skim berbilang pengundian telah diintegrasikan dan dinamakan sebagai Skim boleh suai TXOP berbilang pengundian atau Adaptive Skim TXOP Multipolling (AMTXOP).

Selain itu, pendekatan baru yang menggabungkan skim pengundian dan tugasan TXOP di penjadual HCCA telah diperkenalkan dan dipanggil maklumbalas mudahsuai berasaskan HCCA berjadual atau Adaptive Feedback-based HCCA Scheduler (AF-HCCA). AF-HCCA boleh menampung aplikasi video yang menunjukkan perubahan dalam kedua-dua lat ketibaan kerangka dan saiz kerangka, sebagai contoh aliran H.263. Menerusi skim yang diperkenalkan, ia dapat mengumpukkan jangkamasa TXOP dengan tepat bagi setiap aliran trafik , di mana ia mencukupi untuk menghantar data mereka. Tambahan pula, ia hanya membuat pemilihan QSTAs apabila diperlukan sahaja, untuk mengurangkan kelewatan dan memulihara saluran jalur lebar.

Hasil kajian menunjukkan bahawa F-Poll adalah algoritma yang berpotensi untuk menyokong aliran video dengan kepelbagaian lat ketibaan yang berbeza,manakala skim ATXOP dengan versi yang telah dipertingkatkan, iaitu AMTXOP bermanfaat untuk aliran video, di mana ia menunjukkan perubahan dalam saiz paket seperti aliran H.264. Integrasi antara skim-skim tersebut menunjukkan penambahbaikan untuk aliran video VBR. Keputusan menunjukkan bahawa F-Poll, ATXOP dan skim AMTXOP mengatasi pengundian HCCA dan skim tugasan TXOP dari segi kelewatan hujung ke hujung dan saluran penggunaan jalur lebar, di samping mengekalkan daya pemprosesan sistem. Selain itu, AF-HCCA menunjukkan peningkatan yang semakin tinggi dalam kelewatan paket hujung-ke-hujung dan amat mengurangkan overhed pengundian berbanding dengan bukan sahaja penjadual HCCA, tetapi juga kepada salah satu penjadual peningkatan HCCA terkini yang dikenali sebagai penjadual terperingkat tarikh matang paling awal atau Enhanced Earliest Due Date (EDD).

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I certify that a Thesis Examination Committee has met on 29 March 2016 to conduct the final examination of Mohammed Ahmed Mohammed Al-Maqri on his thesis entitled "Enhancements on Hybrid Coordination Function Controlled Channel Access for Video Transmission in IEEE 802.11E Network" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

AC	Access Categorie.
ACK	Acknowledgement.
ACU	Admission Control Unit.
AF-HCCA	Adaptive Feedback-based HCCA Scheduler.
AID	Associate Identifier.
AMC	Adaptive Modulation and Coding.
AMTXOP	Adaptive Multipolling TXOP Scheme.
AP	Access Point.
ATXOP	Adaptive TXOP Scheme.
AWK	Alfred Aho, Peter Weinberger.
BSS	The Basic Service Set.
CAP	Controlled Access Phase.
CBR	Constant Bit Rate.
CF-Poll	Contention Free.
CFP	Contention Free Period.
CoV	Coefficient of Variation.
CP	Contention Period.
DCF	Distributed Coordination Function.
DEB	Deterministic Backoff.
DTB	Dual Token Bucket.
DTH	Dynamic TXOP HCCA.
EDCA	Enhanced Distributed Channel Access.
EDCF	Enhanced DCF.
EDD	Earliest Due Date.
F-Poll	Feasible Polling Scheme.
FFBI	Feed-Forward Bandwidth Indication.
FTP	File Transfer Protocol.
GI	Generation Interval.
HC	Hybrid Coordinator.
HCCA	HCF Controlled Channel Access.
HCF	Hybrid Coordination Function.
HR/DSSS	High-Rate DSSS.
HTTP	Hypertext Transfer Protocol.
IR	Infrared.
LAN	Local Area Network.
MAC	Medium Access Control.
MSDU	MAC Service Data Unit.
MSI	Maximum Service Interval.
NAV	Network Allocation Vector.
NPHCCA	Non-Polling based HCCA.
OFDM	Orthogonal Frequency Division Multiplexing.
OSI	Open Systems Interconnection.
PCF	Point Coordination Function.

PER	Packet Error Rate.
PHY	Physical Layer mode.
PIFS	PCF Inter Frame Space.
PLCP	Physical Layer Convergence Procedure.
QAP	QoS-enabled Acces Point.
QoS	Quality of Service.
QS	Queue Size.
QSTA	QoS-enabled Station.
RAM	Random Access Memory.
RF	Radio Frequency.
RM	Rate Monotonic.
RTCP	RTP Control Protocol.
RTP	Real-time Transport Protocol.
SI	Service Interval.
SIFS	Short Inter Frame Space.
SINR	Signal-to-Interference Plus Noise Ratio.
SMA	Simple Moving Average.
SMTP	Simple Mail Transfer Protocol.
STA	Station.
TBTT	Target Beacon Transmission Time.
TCP	Transmission Control Protocol.
TGe	IEEE 802.11 Task Group E.
TS	Traffic Stream.
TSPEC	TS Specification.
TXOP	Transmission Opportunity.
UDP	User Datagram Protocol.
UGC	User-Generated Content.
UP	User Priorities.
VBR	Variable Bit Rate.
WLAN	Wireless Local Area Network.
WM	Wireless Medium.

CHAPTER 1

INTRODUCTION

1.1 Background

Recently, IEEE 802.11 has become one of the massively deployed wireless technology in the residential and public places such as apartments, stock markets, campuses, airports, etc. Its key features, like deployment flexibility, infrastructure simplicity and cost effectiveness, have attracted a great deal of research attention toward providing an ubiquitous wireless access environment. This tendency leads to the presence of several multimedia applications with various traffic characteristics which demand different levels of Quality of Service (QoS). It is widely expected that next generation wireless networks will be carrying a large portion of encoded video streams, two-third of all traffics in the networks will be video by 2017 according to Cisco Visual Networking Index (Cisco Visual Networking Index, 2013). Initially, IEEE 802.11 WLAN (IEEE 802.11 Standard, 1999) was designated for the transmission of the best-effort services which is no longer sufficient to meet the tremendous growth of time-bounded services that require rigorous QoS requirements such as channel bandwidth and delay. Since Medium Access Control (MAC) layer's functions are not QoS-oriented, guaranteeing QoS in this layer became a challenging task. Consequently, IEEE 802.11 Task Group E (TGe) presented IEEE 802.11e standard to provide a reliable support of QoS for multimedia streaming over WLANs.

1.1.1 IEEE 802.11 Standard Overview

IEEE 802.11 wireless networks (IEEE 802.11 Standard, 1999) have received a widespread popularity and played a major role in constructing wireless broadband computing environment. It introduces two channel access modes, namely Distributed Coordination Function (DCF) and Point Coordination Function (PCF). The former is the mandatory medium access method which is appropriate to serve best-effort applications such as Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP) and Simple Mail Transfer Protocol (SMTP). However, when many stations attempt to communicate at the same time, many collisions will occur which will lower the available bandwidth and possibly lead to congestive collapse. Besides, all traffic streams, with different needs, are likely subject to a similar backoff process leading to undifferentiated service among high and low priority traffics. For this reason, it is not an ideal environment for multimedia traffics that required a stringent QoS requirements. Multimedia streams that require a rigorous QoS level are served during the controlled mode, PCF, since it provides a contention-free polling-based access to the channel to provide the demanded QoS. However, it is still not efficient enough to support high QoS requirement applications due to the fact that PCF only operates on the Free-Contention period, which may noticeably cause an increase in the packet transmission delay, especially for the high bursty traffics. For this reason, IEEE 802.11e standard (IEEE 802.11e Standard, 2007) and its amendments in (IEEE 802.11e Standard, 2012) have been proposed to address such limitations and to improve the QoS capabilities of WLANs to cover a wide range of QoS needs.

1.1.2 The IEEE 802.11e Standard

IEEE 802.11e extends the MAC of IEEE 802.11 standard by introducing Hybrid Coordination Function (HCF) which presents two medium access modes, Enhanced Distributed Channel Access (EDCA) and HCCA. The HCF basic medium access protocols, namely EDCA function operates in a distributed manner to provide prioritized QoS. Whereas, HCCA introduces a polling scheme to provide parametrized QoS for applications that require rigorous QoS requirements. The EDCA and HCCA are extensions for the legacy DCF and PCF of IEEE 802.11, respectively. In EDCA, the high-priority traffics has a higher chance of being sent than the low-priority traffics, for more details refer to Section 9.19.2 of (IEEE 802.11e Standard, 2012). In other hand, a robuster QoS is supported throughout the polling access mode of HCCA.

Under HCF, a beacon is transmitted by the HC every Target Beacon Transmission Time (TBTT) comprising a superframe which in turn includes Contention Free Period (CFP) followed by Contention Period (CP). CFP is managed by HCCA to transmit packets in controlled access mode, while distributed access mode managed by EDCA during CP. The HC shall initiate a CFP, to deliver its data traffics, or allocate a TXOP to a QSTA in the CP to allow uplink traffics to be transmitted. In both cases, the HC senses the Wireless Medium (WM). When the WM is found idle for a PCF Inter Frame Space (PIFS) period, the HC shall transmit its data during CFP or permit a QSTA to start a frame exchange sequence with HC to cover the allocated TXOP duration. The HC may begin a Controlled Access Phase (CAP) at any time during the CP if the medium remains idle for a time equals to PIFS. HCCA outperforms PCF of legacy IEEE802.11, in that it can be initiated in both CFP and CP in contrary to its ancestor, PCF, which only operates during CFP. When a QSTA intends to initiate a data traffic, it issues a QoS reservation through a special QoS management action frame, called ADDTS-Request containing a set of parameters that define the characteristics of the Traffic Stream (TS), called TSPEC. The fields of the TSPEC and how the HC exploits them in the scheduling process is discussed in details in the next chapter. Figure 1.1 illustrates an example of HCCA transmission during CFP and CP periods (IEEE 802.11e Standard, 2012).

1.1.3 Quality of Service Support in IEEE 802.11e

Quality of Service support in IEEE 802.11e is ensured by means of EDCA and HCCA function. EDCA mechanism provides differentiated, distributed access to the WM. It delivers traffic based on differentiating User Priorities (UP). The

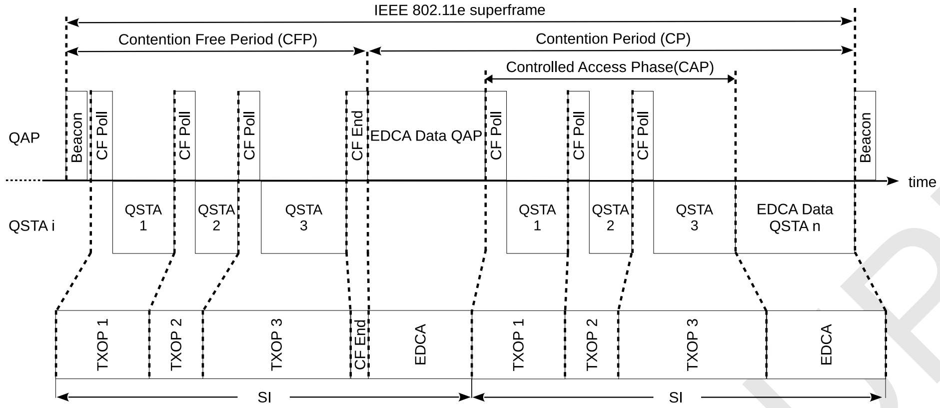

Figure 1.1: Controlled Channel Access Mechanism in IEEE 802.11e HCCA

UP, in turn, are appropriately mapped into four ACs based on their preference. EDCA appoints different contention parameters for each Access Categorie (AC) to deliver the traffic flows according to their priority. Every AC will be associated with a backoff timer so that the highest priority ACs will go through a shorter backoff process. Despite EDCA provides QoS support, it is still not efficient for application with rigid QoS requirements.

In HCCA, the HC uses its high priority access to deliver the downlink TSs. In order to initiate an uplink traffic, the QSTA issues a QoS reservation through transmitting an ADDTS-Request frame. This frame carries information about the TSPEC which is required by HC for scheduling purpose. The HC, which usually resides in the QoS-enabled Acces Point (QAP), maintains the TSPECs for all *TSs* in the so-called polling list. Then, the HC computes the duration of the time to be granted to each QSTA for the transmission of their traffics which called TXOP. The admission of the *TSs* is governed by HC, using the Admission Control Unit (ACU). HC reserves the right to accept or reject any *TS* so as to preserve the QoS of the previously admitted *TSs*. If HC accepts the traffic, it will respond by an ADDTS-Response or a rejection message otherwise. Delay-sensitive multimedia streams are more adequate to be transmitted throughout the polling scheme, HCCA. This approach was designated to minimize the overhead of messaging caused by the distributed approach of EDCA and thus guarantee the required QoS. In HCCA, the HC polls wireless stations periodically and allocates TXOP to their traffics. And yet, HCCA schedules traffics upon their QoS requirements negotiated in the first place. This issue will be discussed in Section 1.2.

1.1.4 Video Sources

Generally, video applications can be classified into two categories: the pre-recorded video and real-time live video. For pre-recorded video, one can analyze the video trace and gain the TSPEC in advance. However, for real-time live video, the traffic characteristics are unknown in advance and the QSTA cannot send an accurate TSPEC of its real-time live video beforehand. For transport over networks, video is typically encoded (i.e., compressed) to reduce the bandwidth requirements.

As shown in Figure 1.2, a video communication system has five major components: 1) The source encoder that compresses video and audio signals into media packets, which are sent directly to lower layers or uploaded to the media server for storage and later transmission on demand; 2) The application layer in charge of channel coding, packetization, and etc.; 3) The transport layer that performs congestion control and delivers media packets through underlying layers (MAC and physical layer) from the sender to the receiver for the best possible user experience, while sharing network resources fairly with other users; 4) The transport network which delivers packets to the client; 5) The receiver that decompresses and renders the video packets, and implements the interactive user controls based on the specific applications. Rate control can be applied during the encoding process to adjust the resulting video frame sizes to the available bandwidth. Although VBR encoding results in variations of the encoded frame sizes, it results in constant quality video (Ortega, 2000) which is suitable for transmission over wireless networks. In contrast, CBR video encoding adjusts the quantization parameter so as to keep the frame sizes nearly constant at the expense of relatively large frame quality variations. VBR pre-recorded traffic in turn can be generally classified into three main categories: a) variable packet size with constant Generation Interval (GI), e.g., MPEG-4 videos; b) constant packet size with variable GI, e.g., voice over internet protocol (VoIP); and c) variable packet size with variable GI, e.g., H.263.

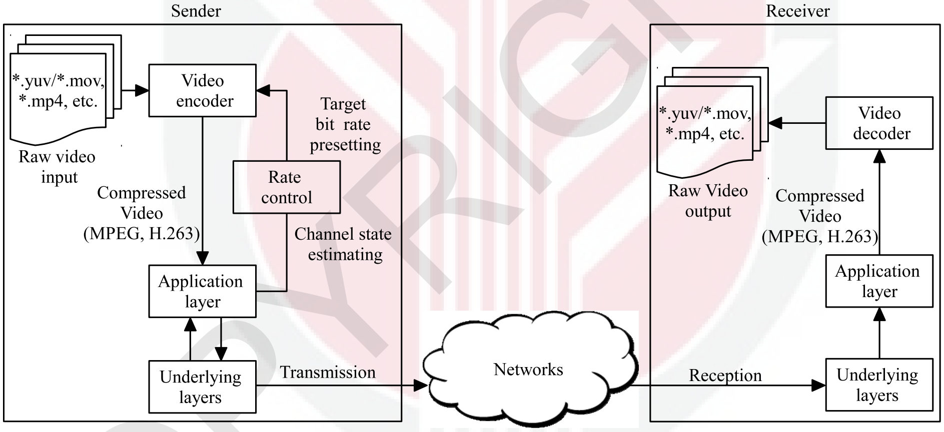

Figure 1.2: Video Transmission System Architecture

1.2 Problem Statement

In HCCA, the HC schedules QSTAs with respect to their negotiated TSPEC parameters which represent the mean characteristics of the traffics. Basically, the weakness of HCCA in supporting VBR traffic is because of the lack of information about the abrupt changes of the traffic profile during the running time. Several enhancements of HCCA have been recently presented aiming at reducing the deviation between the negotiated TSPEC parameters and the actual fluctuation of the video traffic profile. These enhancements use different methods include prediction and estimation of application profile. However, they still not ideal to reflect the actual fluctuation of video during the traffic lifetime. In the case of the transmitting of pre-recorded video traffics, it will be beneficial to inform the HC about the changing in the video profile to accommodate the fast fluctuation of the traffic.

Although HCCA guarantees QoS for video traffic based on the required TSPEC parameters, there is a probability for video traffic of the category (a), Section 1.1.4, of VBR traffics which mentioned in Section 1.1.4 to have frames smaller than the mean negotiated MAC Service Data Unit (MSDU) size. Consequently, larger TXOP than needed is assigned to the corresponding QSTA causing wasting in wireless channel time. Moreover, it remarkably increases the end-to-end delay and degradation in wireless channel utilization. Assuming that for any QSTA in a certain SI, some frames sent are considerably smaller than the negotiated MSDU, in this case only a portion of the scheduled TXOP will only be utilized. Subsequently, the next scheduled QSTA will be initiated unnecessarily late according to its scheduled time, regardless of the actual exploited time in the previous TXOP. This may cause increment in the delay and may waste the channel bandwidth as well. This problem becomes noticeably severe when the number of admitted QSTAs that generate VBR traffics increment.

Moreover, polling all QSTAs at the same SI period may cause deterioration in the channel utilization as some QSTAs are not ready for transmission. In some SIs and due to the varying feature of category (b), Section 1.1.4, of VBR traffics. There may have been one or more QSTAs with no data to be sent. Thus a case of overpolling will be occurred. As a result, the QSTA that have no data in their transmission queue which will reply by Null-frame. In the some other SIs it is even worse where only QSTAs at the end of the polling list utilize the poll and transmit data packets while all proceeding QSTAs reply Null-frames. Polling a QSTA with no data will remarkably increase the poll overhead, which involves transmitting one poll frame, a Null-frame and an Acknowledgement (ACK).

Furthermore, videos that show variability in both frame size and at frame generation time such as H.263, category (c), Section 1.1.4, will mostly suffer from poor QoS support in HCCA. This is because it is neither accurately assigns TXOP to TSs nor prevent over-polling them. Consequently, this cause an increase in packet delay poorly utilize the wireless channel. Although HCCA operates efficiently in heavily loaded network, yet in the increase number of VBR traffics in the network, the delay will drastically increase as the deviation from the mean negotiated TSPECs is noticeably wider. Besides, this will decrease the chance of supporting more number of TSs as the channel time is wasted by the Null-frames messages.

1.3 Motivation

The scheduler is expected to accurately know the status of transmission queues. This theoretical assumption is made in many proposals for centralized scheduling disciplines. Moreover, this assumption is only true for downlink flows, i.e. from the Access Point (AP) to the stations, because the main scheduler is located at the AP. As the uplink transmission queues are located at the user stations, their status is unknown to the AP's scheduler in most WLAN technologies including IEEE 802.11. In most situations, the AP only knows whether there are data on the uplink queues or not.

Moreover, the next generation wireless networks are widely expected to be carrying a large portion of encoded video streams, two-third of all traffics in the networks will be video by 2017 according to Cisco Visual Networking Index (Cisco Visual Networking Index, 2013). With the increase of Internet web applications in the wireless mobile devices, the CBR such as pre-recorded video streams have become more prominent nowadays. As the characteristics of the pre-recorded stream's traffic are available prior to the call setup, the HCCA scheduler shall benefit from this merit to accurately support uplink traffics. To the best of our knowledge, scheduling the uplink pre-recorded continuous media in HCCA has not been addressed efficiently despite the fast growth of uplink streams of the User-Generated Content (UGC) in the Internet such as pre-recorded video streams.

1.4 Research Objectives

The main objective of this thesis is to design a scheme able to provide differentiated QoS guarantees for pre-recorded video traffics over IEEE 802.11 WLAN. The proposed scheme is aiming at minimizing the limitations imposed by scheduling such traffics based on their mean characteristics as in HCCA. This requires extensive QoS support by the underlying technology, which has led this research to focus on IEEE 802.11e WLANs. The aforementioned objective can be divided into the following specific objectives:

- To design a new QoS scheduler that accurately assigns TXOPs to the stations based on their actual needs and mainly aims to enhance QoS support, for video traffics of type (a) (Section 1.1.4), by minimizing the delay, increasing the throughput and improving the wireless channel utilization.
- To design an enhanced HCCA polling scheme to address the problem of scheduling VBR video streams of type (b) (Section 1.1.4) by optimizing the

legacy polling scheme using a feedback about the arrival time of the subsequent video frame of the uplink traffic.

- To design an adaptive scheduler that incorporates enhancements in both polling and TXOP assignment schemes based on the feedback information about the packet arrival time and size piggybacked in each video frame of type (c) (Section 1.1.4) to minimize the experienced delay and alleviate the over polling issue as well as maximize the channel bandwidth utilization.

1.5 Research Scope

As mentioned before, IEEE 802.11e introduces HCF which includes two access modes Enhanced DCF Enhanced DCF (EDCF) (distributed) and HCCA (centralized). As EDCF operates provides moderate prioritized QoS, this research focus on the enhancement of the HCCA polling scheme which provide parametrized QoS for applications that require rigorous QoS requirements.

This research focuses on the transmission of prerecorded video as a key MAC enhancement in the 802.11e standards. It concentrates on the transmission of the uplink traffics from stations to access point as the HC is unable to predict the amount of the data at the station transmission queues. For downlink traffics, HC which resides in QAP maintains separate queues for these traffic streams, thus the HC can allocate time resources for its queues easily.

The proposed schemes are tested under infrastructure wireless network. As the MAC level fragmentation is considered a low priority feature by 802.11e vendors, due to the implementation complexity, it introduces by increasing overhead of fragmentation, this feature was omitted in this research.

1.6 Thesis Organization

The rest of this thesis is organized as follows:

Chapter 2 first presents QoS challenges in IEEE 802.11e WLANs. Then, it discusses the relevant approaches that have been made in the literature to improve the QoS support of multimedia traffics in IEEE 802.11e WLANs. Finally, these approaches are systematically summarized and compared, allowing us to clearly define the existing research challenges, and highlight the promising new research directions.

Chapter 3 first identifies the definitions and conventions used throughout the thesis. Then, it presents the research framework and explores its stages in detail. Finally, the experimental setup and network topologies as well as the performance metrics and their evaluation methods are presented in this chapter.

Chapter 4 presents a novel TXOP scheme called Adaptive TXOP (ATXOP) to support variable packet sizes video traffic transmission over controlled mode of IEEE 802.11e MAC, HCCA mode. Moreover, it presents AMTXOP which leverages the performance of the ATXOP by incorporating multi-polling scheme into TXOP assignment process. It also describes and evaluates the proposed schemes and compares them with other schemes.

Chapter 5 presents a new selective polling scheme called Feasible Polling Scheme (F-Poll) for supporting variable generation interval video traffic transmission over HCCA. It also shows a detailed description of the proposed scheme, in terms of algorithm structure and operations. The chapter also presents the performance evaluation of the F-Poll and compares it with the legacy HCCA polling scheme and one of the state of the art approaches in the literature.

Chapter 6 introduces AF-HCCA, which integrates ATXOP and F-Poll schemes for supporting high VBR video transmission in HCCA mode. It also describes and evaluates the proposed scheduler in different scenarios. Finally, it presents the strength of integrating both ATXOP with F-poll scheme into one system.

Chapter 7 concludes the thesis and recommends some promising directions for future research.

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