Work In Progress: Quality of Service of IEEE 802.11e

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Abstract—Wireless LANs (WLANs) are one of the fastest growing wireless access technologies. Unfortunately, since they were developed to closely match existing wired LANs, the popular IEEE 802.11 standards have several problems in providing Quality of Service (QoS) to stations. Importantly, especially for real-time multimedia services, they do not define support for traffic prioritization or upper bound delay guarantees. The IEEE 802.11e standard is being developed to overcome these drawbacks.

In this paper, we give an overview of the Medium Access Control (MAC) enhancements found in the current 802.11e draft specification. The standard defines two new mechanisms for QoS support, namely the Enhanced Distributed Coordination Function (EDCF) and the Hybrid Coordination Function (HCF).

Index Terms—Delay, Differential Services, IEEE 802.11e, Quality of Service, Throughput.

I. INTRODUCTION

THE introduction of wireless data networks over the past few years has led to numerous wireless extensions of the 802 specifications. IEEE 802.11b, currently the most popular Wireless LAN (WLAN) standard, uses the prevailing 802 LLC protocol but provides an independent Physical (PHY) layer and Medium Access Control (MAC) sublayer specification, allowing support for best-effort wireless communication.

Since WLANs are the successors of existing LANs, they are expected to support the same applications as the wired Ethernet they are replacing. In saturated conditions [1] the performance of certain applications may be unacceptable since WLAN stations share an error prone, restricted bandwidth channel. Extensive efforts are underway to ensure acceptable QoS over wireless mediums [2][3][6]. The WLAN protocols need to evolve to utilize the wireless channel efficiently, avoid contention, and fairly allocate the limited bandwidth to individual IP-based traffic flows where needed.

The Distributed Coordination Function (DCF) and the Point Coordination Function (PCF) of the original IEEE 802.11 MAC layer protocol [7] do not provide a service differentiation mechanism to guarantee a lower bound on throughput or an upper bound on delay.

Due to substantial demand for the transmission of delay sensitive video and audio data, 802.11 task group E formed to develop a MAC protocol with service differentiation. The 802.11e draft standard [8] includes two new MAC schemes to provide QoS to the requesting stations, namely the Enhanced Distributed Coordination Function (EDCF) and Hybrid Distributed Coordination Function (HCF).

In this paper, an overview of the IEEE 802.11 standard and the IEEE 802.11e draft standard is given. Section IV describes the research direction which will be taken.

II. IEEE 802.11

A. Distributed Coordination Function

DCF is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). When a station has data to transmit, it enters a collision avoidance phase where a backoff counter is randomly chosen from {0, 1, …, CW -1}. Initially CW is set to CW_{min}. For each subsequent retransmission attempt CW is doubled, up to a maximum of CW_{max}. When the channel has been sensed idle for a period called a DCF Inter-Frame Space (DIFS), the backoff counter begins decrementing once every idle slot time [4]. If the channel is sensed busy, the backoff counter is paused until the channel is once again idle for at least a DIFS period. Once the backoff timer reaches zero, the station can initiate its frame transmission.

In DCF all stations have equal probability to access the channel and share it according to equal frame rate and not according to equal throughput. This offers no support for priority access to the channel for time-sensitive traffic.

B. Point Coordination Function

This optional mode was introduced as an initial attempt at supporting time-sensitive traffic flows, using a contention free service. The Point Coordinator (PC) periodically sends a beacon frame to broadcast network identification and management parameters specific to the wireless network. PCF splits the time into a contention-free period (CFP) and a contention period (CP). Only stations polled by the PC may transmit during the CFP. The CFP ends after the time announced by the beacon frame or by a CF-End Frame.

Even though the PCF can offer some sort of priority to an overloaded station, it cannot differentiate between traffic types or sources. Therefore, it cannot tell which stations have long queues of time-sensitive traffic, and which only hold best-effort traffic.

Another problem with PCF is that the PC has to contend with other stations to gain control of the wireless medium. Therefore, the starting time and length of the CFP can vary.

These downfalls led to the establishment of the IEEE 802.11e Work Group.

III. IEEE 802.11E

The 802.11e draft standard presents two new MAC schemes; EDCF is an extension of DCF, while the HCF is an extension of PCF. Unlike the original 802.11, where it was not compulsory to have a PC, both EDCF and HCF must boast a centralized Hybrid Controller (HC).

It should be noted, that the aim of ensuring QoS is not to create additional network resources. It is to ensure that the existing network resources are managed in order to provide

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predictable performance to individual traffic flows.

A. Enhanced Distributed Coordination Function

The EDCF is a contention-based channel access mechanism and introduces the concept of Traffic Categories (TCs). Within a station there is a maximum of eight TCs, each having its own MAC queue and backoff counter. A TC begin decrementing its backoff counter once the medium has been idle for a period of time defined by the corresponding TC, called the Arbitration Inter-Frame Space (AIFS). A higher-priority TC will have a shorter AIFS than a lower-priority TC and will therefore be able to decrement its backoff counter more often.

Each TC also has its own CW_{min}, CW_{max}, and Persistence Factor (PF). These vary the probability of the TC winning the channel contention. The PF determines the degree of increase of *CW* when retransmissions occur. Higher-priority TCs will have smaller PF values than lower-priority TCs. In the original 802.11 standard, PF is constantly 2.

Since multiple TCs with different parameters can exist in parallel within a station, there could be internal contention. Internal contention is avoided by letting the higher-priority TC win the opportunity to transmit.

B. Hybrid Coordination Function

The HCF is a continuation of the PCF's polling scheme. As in PCF, together a CP and CFP form a superframe. During the CP, access to the wireless medium is managed using EDCF rules. Thereafter a CFP begins, where a HC sends QoS CF-Polls to stations. A poll awards the station with an opportunity to transmit, specifying the start time and maximum duration during which no other stations within the WLAN will attempt to gain access to the medium. If a station receives a CF-Poll, it is expected to commence data transmission within a Short Inter-Frame Space (SIFS) period, which is smaller than a DIFS. If it does not, the HC can resume control after a PCF Inter-Frame Space (PIFS) time and allocate a new CF-Poll to another station.

As part of a new controlled contention mechanism, the HC maintains a summary of the queue lengths for each TC of each station. This information is sent to the HC by the stations via the new QoS control field during a Controlled Contention Period (CCP). The CCP begins when the HC sends a specific control frame instructing legacy stations to set their NAV until the end of the CCP. The control frame defines the number of controlled contention opportunities, as well as the TCs which may submit requests during the CCP for an opportunity to transmit. To efficiently ensure that non-reception of resource request frames do not do undetected during the CCP, on reception of a resource request frame, the HC immediately transmits an acknowledgement. This acknowledgement includes a feedback field detailing which station's request had been received.

Using the contention summary generated during CCPs, the HC determines which stations, including the AP, will be allocated transmission opportunities during CFP. When a station receives CF-Poll from the HC, the HC does not identify which TC which should transmit data. It leaves the decision to the station. By decentralizing this decision HCF defines a scalable solution for maintaining the QoS of TCs.

An important difference between PCF and HCF is that the HC has priority over all other stations in the WLAN. Since the PIFS is shorter than DIFS and all AIFS, the HC does not have to contend for control of the wireless medium and can initiate HCF access at any time. Thus, stations can be guaranteed predictable transmission opportunity times.

IV. Proposed Research

In [8] prioritized service of heterogeneous traffic flows is provided, using a distributed MAC approach. However, qualitative throughput and delay guarantees, which are needed for time-sensitive traffic, cannot be made.

The addition of a MAC admission control mechanism should be explored, which could allow efficient QoS guarantees to be made to admitted traffic flows. The fairness balance between starvation versus non-admittance of flows should also be considered.

The majority of existing work on IEEE 802.11x performance assumes that there are no hidden stations [5], no overlapping WLANs, and that no transmission errors occur. However, channel quality *does* vary, and due to the popularity of IEEE 802.11b, overlapping WLANs and hidden stations are very much a reality. Therefore, the effect of these issues on QoS guarantees should be investigated.

Since backward compatibility is a necessity, the effect of the HCF scheme on legacy stations should also be examined.

Using the results of the above research, we hope to propose improvement to the 802.11 draft standard, which could provide prioritized QoS guarantees to heterogeneous traffic flows.

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