A Review of the Quality of Service for Time-Sensitive Applications Through Admission Control in 802.11 WLAN

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Abstract Today, the text, voice, and video communications have become the integrated part of our society. All spheres of life, from industry to leisure, now depend upon received data and its reliable and in-time transmission. This paper provides an understanding of the current challenges of Quality of Service (QoS) for real-time application through Admission Control in the network based on IEEE 802.11 WLAN protocol. It explains the gaps in research and limitations that exist in current admission control schemes. The study proposal gives out work method to develop the efficient and effective admission control scheme for 802.11 WLAN and bridge the gap in research.

Keywords QoS · Admission control · Video over IP · Voice over IP (VoIP) Videoconferencing

1 Introduction

In general, the data communication networks can be broad categories as a backbone network and access networks. There are many types of access technologies for deploying access network on campus. Each of these technologies has its own advantages and limitations. In the present and the future scenario, one of the promising candidate access technologies for wireless communication is IEEE

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802.11 Wireless Local Area Network (WLAN) standard. Simplicity in deployment and high bandwidth capacity has led to the rapid deployment of WLANs almost everywhere.

In recent years, there has been consistent growth in the use of real-time communications for businesses [1]. The popular real-time applications are a voice over IP (VoIP), video over IP, videoconferencing, instant messaging (IM), networked games, and other time-sensitive critical applications. The real-time communication employs application program that operates in time domain where the user feels the effect as immediate or real time. In this type of communication, the latency parameters are expected to be less than a pre-defined value which is generally measured in microseconds.

The WLAN based on the original 802.11 IEEE standard is capable of provisioning only best-effort services. Many developments have been proposed over vanilla 802.11 WLAN to improve its performance for supporting real-time communication. Most of the improvements are directed toward enhancing the raw data rate supported by the network. Many variations are suggested to original standard incorporating changes in the specification of PHY layer. One of such improvement proposed is 802.11n standard [2]. The standard proposes the concept of multiple inputs multiple outputs (MIMO), using multiple antennas in wireless stations. This standard also incorporates Frame Aggregation technique for higher data rates. The standard is expected to support data rates up to 600 Mbps.

The improvements in data rates have certainly resulted in better performance offered by WLAN to time-sensitive services. However, frequently it has been observed that the high data rate network based on 802.11n fails to provide QoS guarantees under heavy traffic conditions. Hence, it is necessary to design and implement a mechanism to control the admission of flows in the network to ensure below saturation performance of the WLAN [3].

2 QoS Requirements

In last few years, the interactive multimedia services have gained a lot of importance in almost all occupations. It became, even more, buzzword when personal computers were connected via networks. In service Video on Demand, the client can choose a movie that he/she wants to watch. The contents are delivered via network instantly. VoIP telephony, which is highly interactive, is now widely used to exchange information between people. Many servers store set of audio and video streams. In service audio and video streaming, the client can tune into one of the stored streams using a streaming capable application and consume the content. These enhanced services require definite bounds for the Quality of Services (QoS) metrics such as guaranteed bandwidth, delay, jitter, and packet loss. The different types of services have varying QoS requirements [4]. The typical performance requirement for text-, audio-, and video-based services are discussed in Table 1.

Table 1 Performance requirement for text-, audio-, and video-based services

Class	Application	One-way delay	Jitter*	Packet loss rate
Real time	VoIP, videoconferencing	<150 ms	1 ms	1% (Video) 3% (Audio)
Streaming	Streaming video/audio	Up to 10 s	1 ms	1%
Best effort	Browsing, e-mailing, FTP	Minutes	NA	0%

3 Amendments to IEEE 802.11 Standards

The original 802.11 standard specifies the capability of data rates ranging from 2 Mbps extending to few Gbps. It defines the operation of WLAN at 2.4 GHz in unlicensed the industrial, scientific, and medical (ISM) frequency band. WLANs have a limited coverage area and typically cover up to a maximum range of 100 m. In July 2003, yet another amendment to the original standard was ratified as an 802.11 g specification. Similar to 802.11a, it also uses OFDM allowing the maximum theoretical raw data rate of 54 Mbps but in practical maximum network throughput range is 20 Mbps.

3.1 IEEE 802.11e

All of the amendments 802.11a/b/g employ the enhancements in technology at the physical layer to boost the data rate of the channel. Due to higher data rates, these standards do provide better QoS that original 802.11 standard-based WLAN. However, they do not ensure QoS guarantees to different services as they lack differentiation among services. As an enhancement to MAC layer, an amendment IEEE 802.11e standard was defined. This standard proposes new MAC layer function known as hybrid coordination function (HCF) [5]. The enhanced new standard IEEE 802.11e facilitates running QoS-sensitive services over WLAN. Albeit it offers better QoS performance than its predecessor plain MAC standard, it is not self-sufficient to extend guaranteed QoS in network overload environment [6]. It is, therefore, essential to control the volume of traffic in order to assure QoS support to existing flows. If admission restrictions are not in place to control the traffic allowed into the network, an appreciable throughput degradation and high medium access delay result in unacceptable performance to enhanced services.

3.2 IEEE 802.11n

However, provision of different access categories at MAC layer in 802.11e is allowed WLAN to differentiate the traffic flows and provided different priorities; the usable throughput of 802.11e WLAN was limited to 25 Mbps. In order to cater for higher throughput, another standard IEEE had formed a new task group in 2004. New standard 802.11n for wireless local network communications got ratified in 2009. Standard 802.11n employs the PHY layer technology that can achieve raw data rates up to 600 Mbps [2]. The standard employs MAC layer features to record usable throughput up to 400 Mbps. The standard holds the backward compatibility to 802.11 a/g devices. The fundamental requirement considered for development of this standard was incorporating support for at least 100 Mbps MAC throughput, almost four times the throughput of 802.11a/g. In order to achieve this, the specifications are amended at both PHY as well as MAC layer.

4 Admission Control in WLAN

Even though EDCA provides the service differentiation by using ACs, the QoS guarantees for the flows cannot be assured under near full load [6]. This limitation is due to the finite capacity of the channel. It is possible for the new flow to enter the network and jeopardize the QoS received by existing flows. Hence, employing admission control has become imperative to prevent any degradation in guaranteed QoS due to channel overloading [7]. According to the 802.11 WLAN standards, QoS-aware access point should have the Hybrid Coordinator (HC). This coordinator would decide on the admission of data flow at the access point. Traffic Specification (TSPEC) messages were defined by IEEE WLAN 802.11n task group for negotiating admission control in WLAN. Through this message, wireless stations use to inform the access point HC their traffic flow requirements such as packet size, delay, and service interval and data rate. Based on the prevailing loading of the network, the HC would accept or reject a new flow.

4.1 EDCA Admission Control Mechanisms

Most of the suggested admission control schemes for WLAN are based on network parameter measurement and estimation of channel capacity using theoretical network model [6]. In solely measurement-based schemes, the value of the concerned network parameter(s), such as the channel busy time in a specified interval, is monitored continuously and the call admission decision is taken by comparing measured values with a pre-defined threshold value for that parameter. Model-based schemes seek to develop a suitable model for the MAC process at the node and use this model to predict one of the QoS metrics such as the achievable throughput, the MAC service time, or the queuing delay at the time of addition of new flow into the network. Depending on the predicted value of the underlying metric, call admission decision is taken.

4.2 EDCA Distributed Admission Control (DAC)

DAC [8] is proposed initially as a part of the 802.11e standard but dropped subsequently. It is developed to protect existing flows by denying new flows into the network based on transmission budgets allocated for each (AC). The algorithm is executed in the following manner.

- At QAP (QoS enabled access point), the uplink and downlink transmission time for each AC is measured.
- QAP announces budget and utilization per AC in each beacon interval.
- Each QSTA (QoS enabled station) works out availability of transmission opportunity in each AC which equals to difference between budget and utilization.
- Each QSTA determines whether there is a scope of adding new flow or increasing transmission in each AC based on availability calculated above.

4.3 Two-Level Protection Scheme

This scheme [8] is an extension of DAC. At first level, the scheme attempts to protect existing priority flow from other priority flows, both existing and new. At second level, a protection is provided from best-effort traffic. First-level protection is implemented by enhancing the DAC algorithm by adding two new techniques known as early protection and tried and known. With early protection, no new flow is admitted using the same principle of DAC. With tried and known technique, a newly added flow is killed if guarantees of flows cannot be met with. At second level, the best-effort traffic is deferred further and further by increasing initial contention window size and inter-frame spacing. The main issues of the implementation are same as DAC scheme.

4.4 Admission Control Based on Threshold

In this scheme, each wireless station measures the traffic on the channel. Two different ways are proposed for admission control. One is based on relative occupied bandwidth and other is based on collision experienced by stations.

- In relative occupied bandwidth scheme, each station measures the busy time of the channel over a sample window period and calculate occupied bandwidth (B_{occu}) as the ratio of busy time to window time. Two different threshold values, T_{high} and T_{low}, are defined. When current B_{occu} is lower than T_{low}, then inactive AC is activated. If B_{occu} is more than T_{high}, then low priority AC is deactivated.
- In collision-based admission control, all stations calculate average collision as the ratio of a number of collisions occurred and the number of transmissions made over sample window period. Again, two thresholds are defined for making a decision in a similar way as done in the technique described above.

When the channel traffic is between the threshold values, the admission control schemes do not kick in any action. When the network load goes above the higher threshold, admission control scheme stops the transmission from the lowest priority active AC for the next beacon period. When the network load goes below the lower threshold value, the highest priority inactive AC resumes the process during the next beacon period. The implementation of this admission control scheme is very easy on both infrastructure and ad hoc WLAN mode. However, the challenge is to set appropriate threshold values. Also, the low priority data flows are stopped and started intermittently degrading service to flows in those access categories.

4.5 Model-Based Admission Control

In IEEE 802.11 WLAN admission control scheme, most of the proposed schemes are based on two-state Markov chain model in the literature [9]. The method tries to estimate the achievable bandwidth by the existing data flows if a new flow with certain parameters is admitted. On calculation, if it is found that the new flow can meet its own QoS requirements without threatening the QoS guarantees for all other existing flows; then only new data flow is permitted in the network. In the literature [10], the proposed model considered the EDCA parameters, i.e., transmission opportunity (TXOP), contention window minimum CW_{min} and measured collisions in the network. Bianchi Model for DCF and Extension of Bianchi Model for EDCA are two main schemes for measurement of available bandwidth in a WLAN [9, 11].

5 Research Gaps

The study presents the aim and design criteria of 802.11ax protocol for QoS provision in WLAN [12]. The study concludes that a design of perfect PHY and MAC layer protocols for advanced WLAN is a daunting task. The research further emphasized upon the need of appropriate admission scheme for ensuring the QoS for the video traffic. Mansoor et al. (2017) proposed feedback admission control in order to ensure maximum utilization of a channel capacity [13]. The scheme utilizes the piggyback information for decision making. For testing, performance study used MPEG4 video traffic and considers the end-to-end delay and unutilised time of the channel for IEEE 802.11e WLAN. A fuzzy-based admission control system (FACS) to estimate the performance of the FACS suggested a system for 803.11e WLAN [14]. There is a need to develop an improved admission control for more advanced protocols like 802.11n.

The authors showed the concept of dynamically adapting the contention window has been presented to optimise the network performance in IEEE 802.11e wireless networks [15]. The study considers the various network parameters for resetting contention window. The study has considered the standard 802.11e. There is need to extend the work to the newer protocol to evaluate the strategy proposed for network optimisation for QoS. This study presents the aspects related to the performance degradation in WLAN [16]. It also proposed a mechanism for improving the QoS in 802.11e WLAN. The scheme proposes adjusting the contention window backoff timing based on active wireless stations. The scheme measures the delay, throughput, and collision rate for different traffic scenarios. The scheme needs to be extended to the 802.11n by improving the model developed for measuring collision rate in 802.11e. The focus has been on adjusting two MAC layer parameters related to the transmission timing control in 802.11e WLAN [17]. The study proposes a throughput control scheme based on the queue length and virtual collision rate. The scheme results are validated for 802.11e WLAN and need to be confirmed for newer WLAN standard such as 802.11n.

6 Conclusions and Recommendations

In this paper legacy, IEEE 802.11 MAC layer QoS limitation is discussed [18] and the review explained added features of the IEEE 802.11e standard that support QoS features for time-sensitive applications in WLANs. QoS support limitation of 802.11e under heavy load provoked many to research into the field of admission control. The good admission control mechanism is to protect admitted flow in WLAN from the new request and allowing the maximum traffic flow according to the capacity of networks. Furthermore, this review looked at the literature on modeling the bandwidth availability and delay analysis for WLANs using analytical models. Hence, it necessary to present a model based on measurement of network parameters to reduce computation complexity, for throughput and delay estimation in WLAN.

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