QoS Guarantee for VOIP over Wireless LANs

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Abstract

Voice over Internet Protocol (VOIP) is one of the most notable applications of internet. Some other well known terms used for VOIP in literature include IP telephony or Internet telephony. It can be a better replacement for the traditional telephone systems because of its high resource utilization as well as low cost. Beside this, wireless LAN Network (WLAN) has emerged as a robust networking technology. Hence, the combination of these two popular technologies is growing so fast all over the world. Voice over WLAN (VoWLAN) will be an infrastructure to provide low-cost wireless voice services. However, similar to other wireless applications, VoWLAN has also faced numerous challenges that need to be considered. Quality of Service (QoS) is one of the essential challenges in all kind of wireless applications. In this study, we have critically reviewed the most important QoS requirement; the challenges imposed by these applications as well as some of the QoS enhancement methods.

Keywords: *Voice over IP; Quality of Service; Voice over Wireless LAN; 802.11e*

1. Introduction

With the advent of wireless networks in the communication technology domain, there are many applications which are benefitting from out of exploiting robust features of wireless networks. Among numerous applications of wireless network, Voice over IP (VOIP) is one of such applications. A major underlying reason behind this fact is its capability of accepting the challenges of the real time delivery of packet voice across networks while exploiting the ubiquitous internet protocol (IP).

Cai, *et al.*, [1] discussed the concept of transmission of voice over packet switch network in detail. Since the last two decades, IP telephony service has advanced tremendously; One can anticipate it as a viable alternative to the conventional voice service being exercised over public switched telephone networks (PSTN) due to its cost effectiveness factor.

Wireless Local Area Networks (WLANs) are a rapid emerging networking technology which has been frequently deployed across the continents. The prime benefit of WLANs lies in its tractability, simplicity, flexibility and the last but not least, cost effectiveness. Almost, a decade ago, the IEEE 802.11 WLAN starts gaining its popularity till it become a ubiquitous networking technology resulting into its mass level deployment around the world. However, literature review indicates that overwhelming majority of existent Wireless LAN applications are serving in the domain data centric (such as file transfer), web browsing and electronic mail; thus there is an ever increasing demand of multimedia services over WLANs.

Compounding both of these notable technologies into a new breed of technology Voice over WLAN (VoWLAN) has been coming forth in shape of an infrastructure for the provision of low-cost wireless voice services.

Apart from these prefatorily advantages and traits of VoWLAN, this technology inherently suffers from a few shortcomings which requires to be addressed. One such non trivial issue of VOIP is obtaining guarantee for quality of service (QoS). Quality of Service (QoS) can be described as the ability or potential of a network's infrastructure to deliver coherent, uniform, and consistent predetermined outcomes. We in fact, can introduce QoS within a given network at numerous stages and levels. The QoS can be deployed at the network adaptor, a router, a server or event at an application level. However, in the domain of wireless networks in particular, QoS can be deployed only at the network adaptor level; because it is a fact the routers and applications are not usually well aware of the connection medium. Moreover, to make ensure an acceptable level of data integrity, bandwidth management and queuing are priorities when endeavoring to furnish a satisfactory service in a non-wired network for applications such as VoIP and Media Streaming.

There are numerous factors which can deteriorate the quality of voice in VoWLAN; these include IP network service problems such as delay, delay jitter and unreliable packet delivery. All of these issues pose significant challenges during and after the process of deployment of voice traffic over WLANs. The physical and MAC layers suffer from substantially degraded performance characteristics when compared to its peer counterpart that is wired local area network. That is why, the applications of VoWLAN elicit numerous deployment issues relating the network QoS provisioning, capacity, admission control and system architecture as well.

So far, in this section, we described the introductory information about VoWLAN along with some of its essential problems. In the next section we shall focus on the QoS requirements and challenges for VoWLAN. We first describe QoS parameters for VoIP in Section 2. In Section 3 we present QoS enhancement mechanisms in WLAN MAC layer protocols. Finally in Section 4 we discuss the conclusions.

2. QoS prerequisites

All Intractability of obtaining guarantee in QoS is one of the nontrivial issues with the deployment of VoIP. The Figure 1 indicates a general overview of the process of achieving QoS in VoWLAN. The Figure 1 has shown some particular milestone in obtaining the desired level of QoS. We shall discuss each of them one by one. It is useful if we categorize the parameters related to the quality of a single conversation with VoIP. Three parameters have been discussed as follow.

- latency (end to end packet delay)
- delay jitter (delay variation)
- Packet loss.

Latency or delay in transmission is one of the significant differences between VoIP and data applications. The web data transfer, e-mail, file transfers and other such data applications are far less prone to be sensitive to latency as compared to reduction in throughput. It is quite normal and permissible if a delay of seconds in transmission of a data file is observed; however, a latency of tens of milliseconds in a voice call is immediately obtrusive and not easily ignorable; which may lead to intolerable annoyances. ITU-T G.114 has presented its recommendations for the maximum length of one way end to end delay which is described as 150 ms for maintaining a reasonable quality for the conversation [1]. Moreover, the voice quality is acceptable for a latency not more than 400ms but with an echo canceller [1]. However, this delay constraint turns to be much more stringent when no echo canceller is adopted, and the end to end delay is restricted to 25ms for adequate level of acceptable quality. The applications with VoWLAN, total delay are a function of codec delay, packetization delay and network delay in both the backbone network and WLAN.

Delay due to jitter or delay variation which occurred primarily due to the network dynamics, has even more negative effects on quality of voice quality as compared to other delays. The information from source to destinations is transferred in form of little messages; these messages are termed in the name of packets. These packets experience certain delays of reach ability to their expected destinations. Jitter adversely affects quality of the service in demand. Although it incurs certain sounds due to packet loss; however it can be managed via jitter buffers. Since the WLAN is presumably prone to the bottleneck, delay jitter in the WLAN acts in the capacity of being dominant part. The delay jitter is primarily due to the random channel service time with the CBR traffic model for voice; the time duration the network interface is supposed to be adopted with successful transmission of a frame over the WLAN, which is calculated by the MAC protocol and the data transmission rate. Delay jitter may be eliminated by means of adopting a small playout buffer at the receiver end with the implementation of an efficient playout algorithm [21]. Those packets which do not arrive at the receiver in time, they are susceptible to be dropped. A care must be taken in selecting the size of the playout buffer size because large playout buffer size may incur extra delay while small buffer size may cause in substantial loss of packets.

Packet loss is another issue; data packet congestion in the network, errors and or small buffer size may prone to drop the packets. In voice, there is no way to recover these packets cause once these packets are lost, there is no possibility to recover unless otherwise retransmitted; however as sender can't do it automatically so they might be lost forever. This affects the efficiency resulting into the poor quality of sound finally. QoS monitoring ascertain congestion and queue management to mitigate the volume of data loss. This monitoring is executed through many tools; some of them include Custom Queuing (CQ), Priority Queuing (PQ). Queue management forestalls queues from filling while providing space for high priority packets.

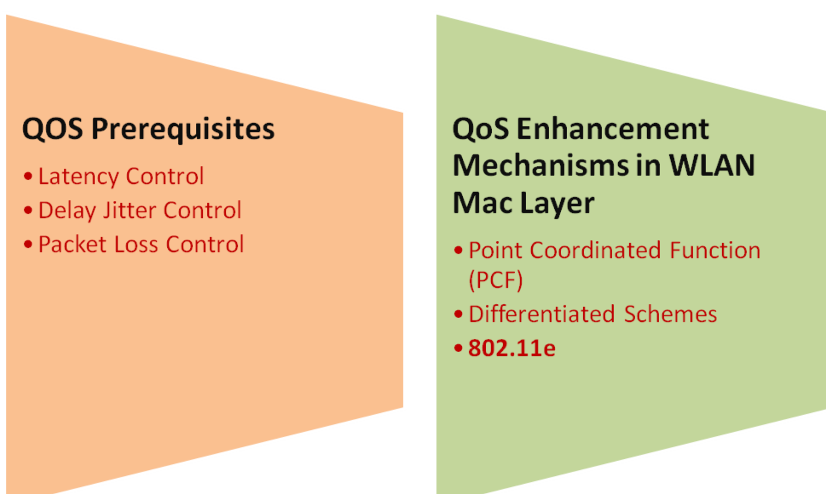

Figure 1. Steps involved in QoS Guarantee for VOIP over Wireless LANs

3. QoS Enhancement Mechanisms in WLan Mac Layer

In previous sub section, we described some important aspects of QoS prerequisites with preliminary review. Now as a subsequent process shall specifically discuss QoS enhancement in WLAN MAC layer. In this section we describe QoS performance of WLAN MAC layer protocols. A careful review of literature reveals that in last decade, Wireless Local Area Networks (WLANs) and particularly IEEE Standard 802.11 has come up with promising popularity. With the ever increasing popularity of WLAN technology, real-time applications such as VoIP have become popular. There are three important parameters for a VoWLAN are [2]:

- Security issues
- WLAN QoS mechanisms
- Handset availability

The WLAN Access Points for VoWLAN networks pose serious bottlenecks. Hence strategies for VoWLAN network management are required to be addressed prior to deployment of VoWLAN. It is essential to design a MAC protocol with QoS support to voice traffic in order to support voice as well as data applications over WLANs [1]. To implement a suitable queue management scheme, designing an efficient playout buffer algorithms, and increment the transmission rate with a more efficient physical layer protocol, etc are some significant parameters that should be considered.

With the advent of legacy 802.11 DCF (Distributed Coordination Function) mode, all stations, including the AP (as if available) compete for channel access with the same priority. There is no mechanism to delegate higher priority to real-time traffic with rigorous QoS requirements. In the MAC layer, two principal approaches have been presented for an improved support for real-time applications: the polling-based mechanism and the prioritized contention-based mechanism.

3.1. Point coordinated function (PCF)

PCF is a Media Access Control (MAC) technique which is used in IEEE 802.11 based WLANs. The optional PCF mode is accessible in a centrally controlled WLAN, using a polling-based mechanism targeted towards guarantee delay for real-time applications [1]. With larger inter-poll periods, more voice connections may be accommodated at the expense of an increase in delay. In literature, Adaptive polling schemes have been introduced [3]. These schemes are aimed towards improvement in the bandwidth utilization while exploiting the voice traffic characteristics [3]. This scheme was compared to the round-robin polling scheme under high traffic load and it was found that it has the potential in obtaining improved throughput and delay performance by means of introduction of a talk spurt detection algorithm into the system. However, PCF is not an ideal solution for real-time traffic [4]. We can summarize these situations in three important points as below:

3.1.1. Increased Traffic Load: When the traffic load increases the inefficient or complex centralized polling schemes cannot achieve desired performance [5]. There is always a trade-off between the efficiency and complexity of polling schemes. In addition, in the PCF mode, all communications have to go through the PC, which prolongs the delay in WLANs.

3.1.2. Stretch Effect: The incompatible co-operation between the DCF and PCF may cause so-called stretch effect.

3.1.3. Uncontrolled Delay: Unknown transmission durations of polled stations may introduce uncontrolled delay for other stations.

PCF can only provide limited QoS for voice traffic due to the reasons mentioned above; thus it is not widely adoptable as an acceptable solution generally for VoWLAN systems.

3.2. Differentiated Schemes

To provide an improved QoS for multimedia applications in IEEE 802.11 WLANs, differentiation schemes have been presented. Service differentiation can be achieved using priority queue management schemes with or without employing various MAC parameters for many but unlike classes of traffic.

With priority queue schemes, traffic is categorized into different priorities and each class of traffic occupies a separate queue. Within a station, packets buffered in a higher priority queue will be served earlier as compared to those in a lower priority queue. The higher priority queue serves the real-time (RT) traffic, such as VoIP traffic. On the other hand the lower priority queue serves the non-real-time (NRT) traffic. The dual queues can be easily implemented in the driver of any 802.11 devices. In this way, only software upgrades are needed for 802.11 WLANs to provide certain level of QoS for real-time applications.

A similar but more complicated approach was proposed in Reference [6], which also used software upgrade-based approach with two separate queues for RT and NRT traffic. Instead of using the strict priority queue, it adopted the earliest deadline first (EDF)-scheduling algorithm for RT traffic, and an adaptive traffic smoother to regulate NRT traffic.

It has been experienced that the performance of VoIP can be enhanced substantially when VoIP traffic is separated from TCP traffic. The priority queue mechanism is well suitable for WLANs with only voice and data traffic. In a more complicated environment with heterogeneous traffic, such as video, voice, and data (interactive or non-interactive), how to extend the dual-queue approach and assign priorities to different traffic categories is a very challenging issue. On the other hand, in the MAC layer, when multiple stations compete for transmission, higher priority traffic may use smaller contention window, slower backoff speed, or shorter IFS to obtain higher priority for transmission, and real-time traffic may allow less or no retransmission to reduce delay [6-10]. In Reference [8], the inter-frame spaces (IFS) are differentiated to provide priority access. In Reference [9], priority schemes by differentiating the initial and maximum contention window have been proposed. In Reference [10], three priority schemes have been proposed: static priority scheduling (SPS), prioritized DIFS time mechanism, and prioritized backoff time distribution mechanism (PBTDM). Note that the scheme in Reference [7] is a special case of PBTDM.

Nonetheless, the above mentioned service differentiation schemes may not be operated well in heavy-load WLANs. For instance, smaller contention window sizes will result in more channel collisions due to contentions. As a result, higher priority frames may have even lower throughput and higher delay due to more collisions. This problem, referred as priority inversion problem [14, 15]. To address this problem, appropriate admission control schemes [16] or adaptive tuning of parameters have been proposed [17]. In conclusion, to support voice traffic over WLANs with QoS guarantee, both admission control and QoS-enhanced MAC are needed.

3.3. 802.11e

IEEE 802.11e-2005 or 802.11e is an approved amendment to the IEEE 802.11 standard that defines a set of Quality of Service enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer [18, 19]. The enhanced DCF (EDCF) is an extension of DCF with four levels of statistical access priority, enabling different traffic categories to be served in different priority queues. The contention-based channel access function of IEEE 802.11e, EDCF, adopts eight different priorities, which are further mapped into four access categories (AC). Access categories are achieved by differentiating the arbitration inter-frame space (AIFS), the initial contention window size, and the maximum window size.

With a smaller AIFS or window sizes, the higher priority class of traffic has a better chance to access the wireless medium. Although different priorities are implemented in EDCF, access to the medium is still determined according to the basic CSMA/CA mechanism. Therefore, EDCF is a prioritized contention-based mechanism.

An extension of the PCF option known as hybrid co-ordination function (HCF) is proposed, which negotiates connections between an AP and the mobile stations, along with specifically assigned transmission durations for each frame. HCF also implements priority queue for different traffic categories so that voice traffic always has the highest priority than other traffic. Therefore, HCF is a hybrid of prioritized contention-based and polling-based mechanism for QoS provisioning. Unlike PCF, there is no specific boundary between the CP and CFP in 802.11e.

The direct link protocol (DLC) allows two stations to communicate unswervingly in the infrastructure-based WLAN, which significantly improve the network performance. The group ACK mechanism, in which the receiver sends one ACK for a number of data packets received, can also reduce some overhead. These new features of 802.11e can definitely improve the performance of voice traffic in a WLAN. However, there are still some concerns about the QoS guarantees that the protocol aims to provide. In polling schemes HCF experience the same complexity-efficiency trade-off as PCF suffers from. It is very difficult to analyze the network performance of the 802.11e and to find the optimal parameters to achieve the best performance due to the complicated QoS provisioning mechanism specified in the protocol. Xiao, *et al.*, [11] developed the analytical model for backoff-based priority scheme for EDCF; which was further improved by the same authors [12, 20].

4. Conclusion

In this study, we have presented an overview of QoS parameters and challenges for VoWLANs. Moreover, we have cynically examined the most important QoS requirement; the challenges incurred by the real world applications as well as some of the QoS enhancement methods. We also described WLAN IEEE 802.11 QoS enhancement mechanisms in the MAC layer. In order to obtain the transmission of both voice and other data traffic in the wireless medium, it is essential to design a MAC protocol with QoS support. The 802.11e standard is an assuring and an efficient mean for QoS support in WLANs for a wide variety of applications. VoWLAN is a promising but very challenging technology which needs more efforts to achieve potential success in the future.

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