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A Survey on Enhancement of Quality of Service in Wireless Data Networks

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Abstract: Quality of service (QoS) is an important consideration in networking. QoS provisioning for wireless networks is a difficult problem due to the self-organizing nature of such networks, and due to strict energy constraints which greatly restrict the signalling overhead. This paper discusses the challenges and solutions involved in providing QoS in wireless data networks. Multiple techniques for providing service guarantees are presented, including data link layer QoS schemes, network layer schemes, integrated (multiple layer) approaches, QoS routing, dynamic class adaptation, and techniques for reservation and admission control.

Keywords: Wireless data networks, QoS, Throughput, Delay Congestion, Fading, Interference, MANET

I. INTRODUCTION

Reliable network performance has long been an important factor for many network applications. However, with an increasing amount of audio and video being sent over public, packet-switched networks, the ability to provide quality of service (QoS) guarantees may be more important in today's networks than it ever was. As such, a good deal of effort has been applied to the task of finding ways to provide reliable network performance while at the same time utilizing the total network resources in an efficient manner.

The challenges associated with providing service guarantees are numerous, but the biggest challenge for traditional networks has been congestion[1,5]. For this reason, a completely different set of QoS techniques are required for wireless networks than for wired networks.

Service guarantees are typically made for one or more of the following four characteristics. A guarantee of delay assures the sender and receiver that it will take no more that a specified amount of time for a packet of data to travel from sender to receiver. A guarantee of loss assures the sender and receiver that no more than a specified fraction of packets will be lost during transmission[2,3]. A guarantee of jitter assures the sender and receiver that the delay will not vary by more than a specified amount. Finally, a guarantee of throughput assures the sender and receiver that in some specified unit of time, no less than some specified amount of data can be sent from sender to receiver.

The remainder of this paper is organized as follows. The second section is an overview of QoS what applications require QoS guarantees, what the challenges are, and some well-known QoS approaches. The third section describes some wireless QoS schemes that work on the data link layer. The fourth section describes some schemes involving QoS routing. The fifth section describes the challenges and solutions involved with QoS in partitioned networks.

II. QOS OVERVIEW AND BACKGROUND

This section provides an overview on QoS, the applications that typically require QoS, challenges of wireless QoS. The final part of this section describes QoS in terms of the user's perception of quality.

A. Applications Requiring QoS:

There are several applications that require service guarantees in order to function properly. These applications are described in this section.

First, and probably foremost, service guarantees are required to properly transmit audio and video. One motivation behind these offerings is that there is unused bandwidth in the IP network that can be utilized for a fraction of the cost of a dedicated, circuit-switched network.. A particular challenge of audio/video transmission is that, for maximum efficiency, some compression methods encode the streams at a variable bit rate (VBR)[1].

Second, real-time systems that are connected to a network require a constant stream of data which matches or exceeds their throughput rate.

B. Challenges of Wired QoS:

There are many impediments to providing service guarantees in a network. Following are some of the challenges present in both wired and wireless networks.

The primary challenge in providing QoS is network congestion and multi-path routing[5].

C. Wired QoS Schemes:

Several schemes have been devised which provide QoS in traditional networks. One method for providing QoS is built into the Asynchronous Transfer Mode (ATM) protocol[8]. ATM is a packet-switched network that makes use of virtual circuits. A virtual circuit is established during a setup phase in which the path from sender to receiver is fixed and resources are allocated at each hop.

Another QoS scheme is called Integrated Services (usually abbreviated as IntServ). IntServ uses a call setup stage to reserve the path from sender to receiver and allocate resources at each hop. IntServ reserves resources on a "per-flow" basis where a flow contains all the network traffic associated with a single application. Unlike ATM, IntServ operates over a heterogeneous network that may have a mixture of IntServ and non-IntServ traffic flowing through each node. As a result IntServ must take measures to guarantee an upper bound on the queuing delays at each hop. IntServ also provides a "controlled-load" service that makes no hard service guarantees, but is designed for real-time multimedia applications.

The next QoS architecture is Differentiated Services (DiffServ). In DiffServ, hosts on the edge of the network mark packets with the class of service they should receive. The primary advantage of DiffServ over IntServ is that there is much less complexity, and therefore greater efficiency, due to the fact that routers do not need to remember details for multiple flows.

However, it can be difficult to implement DiffServ on a heterogeneous network, and it is possible for service guarantees to be violated across the entire network if a single edge host does not mark and shape traffic correctly.

D. Challenges of Wireless QoS:

All of these obstacles of wired network exist in wireless networks, and an additional set of challenges are added that only exist in wireless or mobile networks. As a result of these additional impediments, QoS schemes used in traditional networks may not be feasible in wireless networks.

The first challenge of QoS in wireless networks is severe loss. A wireless link, however, typically suffers much more loss due to data being corrupted during transmission[9]. One cause of loss in wireless transmission is fading, in which multiple versions of the same signal are received at the destination. This interference may come from other communication occurring on the same frequency, electrical noise, or possibly even intentional communication jamming.

Another obstacle in wireless QoS involves propagation delay. Some wireless networks span distances that are measured in kilometers.

E. User Perceived Quality:

A final consideration when discussing QoS is user-perceived quality. It must be known what kind of service guarantee is required for a particular application . It would be wasteful to reserve resources beyond these needs. Also, by knowing which service characteristics are less important, the network can make better decisions regarding what to sacrifice, if necessary.

It has been found that when users are surfing the web or reading e-mail, they are more tolerant of increased loss than they are of decreased throughput. Similar studies have been performed for other applications such as audio and video.

III. QOS SCHEMES AT THE DATA LINK LAYER

QoS schemes can work on various parts of the network architecture. Much focus has been placed on the data link layer of the protocol stack. This section contains descriptions of some such QoS architectures.

A. 802.11e:

802.11e is an extension of the popular 802.11 wireless LAN protocol. This extension enables multiple service levels and can provide service guarantees for network traffic. The first modification made by 802.11e applies to networks that make use of the distributed coordination function (DCF). DCF is a contention-based media access method that is present in 802.11[6]. In DCF, the winner of the contention is the sender that transmitted first, as determined by a random function. 802.11e proposes an enhanced distributed coordination function (EDCF) in which higher priority traffic will wait for a shorter amount of time before transmitting than lower priority traffic[4].

The second modification made by 802.11e only applies to networks in infrastructure mode. If the hybrid coordinator (HC) determines that the channel is idle during the contention period, it can initiate a contention-free controlled access period (CAP). During this period, the HC transmits frames and polls stations to allow them to transmit.

B. Adaptive Inter-frame Spacing (AIFS) in 802.11:

Though 802.11e is a vast improvement over 802.11 in terms of the potential for QoS, many people have identified improvements that can be made to 802.11e in order to make it even more capable. One example is the proposal for adaptive inter-frame spacing described in [4,5].

In AIFS, the EDCF in 802.11e is extended so that the IFS is modified when the link quality changes. When link quality degrades, the IFS for high priority traffic increases and the IFS for best effort traffic decreases.

C. INSIGNIA:

One well-known and often-cited method for QoS is INSIGNIA. Though based on IP, this architecture is presented with data-link layer architectures because of the key improvement offered by INSIGNIA: in-band signaling.

INSIGNIA proposes that soft-state resource management be used in reservations. In this scheme, a reservation is only maintained for a certain amount of time and if no packet is received for some time, then the resources is released.

D. Cross-layer Scheduling and Adaptation:

Some actions can be taken in the physical layer to improve quality of service. The architecture combines QoS reservation and scheduling at the MAC layer with adaptive modulation and coding (AMC) at the physical layer[4].

In AMC, the method for transmission changes when the link quality changes. For example, if the link quality degrades, the physical layer may start transmitting using BPSK instead QAM-16. As a result, more time will be required to send the same amount of data, so the MAC layer must adjust its scheduling accordingly. Using this scheme, throughput performance closely matches the performance of the channel. Due to the fact the bandwidth requests are sent infrequently and only the amount of bandwidth that is required at any given time is reserved.

E. Contention-based QoS in Wireless Networks:

Several people have researched efficient ways to provide service guarantees in contention-based MAC environments since such circumstances are common in MANETs. It is built on a previous contention scheme called contention resolution signaling (CRS) in order to provide service guarantees and make more efficient use of the available spectrum. The paper also explores the abstractions used when evaluating a wireless network.

A wireless network uses spectrum, rather than the "link". The spectrum is the scarce resource with which QoS schemes are concerned. If the wireless network is viewed as a continuous vector space in which physical space and spectrum may be allocated for transmission, then all available resources can be used more efficiently.

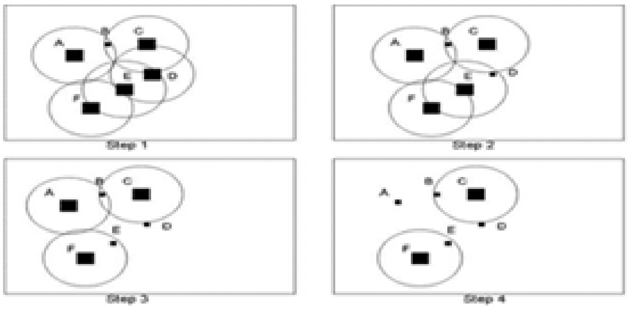

Figure 1: Contention Resolution in CRS

CRS is an architecture suited for a MANET with several nodes spread out over physical space such that all nodes cannot communicate directly with each other[10]. A node that wants to transmit will send a signal in one of several "slots" in a CRS frame.

The addition of an RTS-CTS mechanism reduces interference when there is a hidden terminal.

Resource reservation can be allowed by adding a QoS slot to the beginning of the priority phase. The QoS slot is used for reserving bandwidth in the network.

IV. CLASS ADAPTATION SCHEMES

QoS-enabled networks provide different levels of service to different classes of traffic. Some QoS schemes propose that the class of traffic should be modified as a result of events occurring in the network. This section describes some such schemes.

A. Adaptive Management:

In many QoS schemes, the service guarantees of some traffic can be compromised if significant changes to the network occur, such as the admission of new clients or a degradation of link quality.

In the proposed scheme, traffic is divided into a number of priority classes where some classes get a greater fraction of the channel than others. As such, the priority of the traffic is specified, but not necessarily any other service guarantees. If a new client is added, all other clients of the same class will receive a lower level of service. So in order to receive the same level of service, some or all of the clients could raise their priority level. Whether the clients raise their priority level would depend on the application that is being used and the perceived QoS of the users.

V. QOS ROUTING SCHEMES

Any successful QoS architecture in a multi-hop network requires a routing algorithm which will select a path that can meet the desired service requirements. The following section discusses some of the issues and solutions involved in QoS routing.

A. Wireless QoS Routing:

In ad-hoc networks, routes must be chosen in such a way that per-flow QoS requirements are met and the total bandwidth is well-utilized. In order to set up a route, it is necessary to contact every potential node to determine its level of load and whether it can provide the service level guaranteed to the flow. The first element of the proposed system is a hybrid routing function that stores information about each node in order to determine if a QoS-assured path is available. The network is only flooded if a path is not found using the stored information. Routing function determine the lowest-cost link from the set of available links.

Simulation results show that the proposed routing system offers the same rate of success in finding a delay-constrained path compared to purely flooding protocols, while significantly.

B. QoS in Partitioned Networks:

The final section of this paper discusses some challenges associated with QoS in partitioned networks. A partitioned network is a network that is divided into two or more sections. In such networks, an end-to-end connection may be made across multiple network sections, but the nodes of one section are unable to communicate with the nodes of another section.

a. QoS Challenges and Solutions in Partitioned Networks:

Wireless military networks are typically partitioned in such a way that data must flow between encrypted and unencrypted sections of the network. Refer to figure 2 for a diagram of such a network. [7] discusses QoS-related issues in these types of networks and provides some solutions that allow some level of QoS.

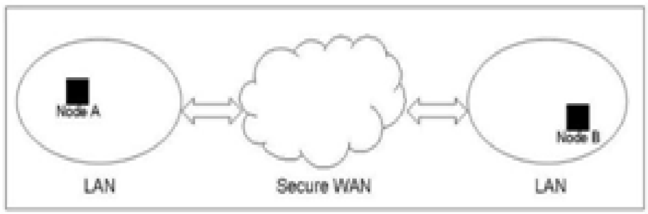

Figure 2: PArtitioned Network

The first proposal for providing QoS over a partitioned network is for the nodes of one network section to measure the performance of another section as a whole.

Second, it is possible for the nodes in one network section to determine if another section will suffer from blockages due to terrain, interference, or other causes[6]. This blockage can be detected by measuring the network section in question, or by making use of other sensors to predict conditions that will cause blockage.

Next, it is possible to improve throughput and reduce the network utilization by combining small packets into larger packets and by compressing the data. By combining packets, a fewer number of packet headers will be sent, which will reduce the total amount of traffic sent while not reducing the amount of meaningful data sent. Compression can increase the rate of transmission for meaningful data, but only if the data transmitted can be compressed.

Finally, more reliable transmission can be achieved by treating the network sections as independent networks and setting up a TCP connection across each network. If a TCP proxy is placed on either side of a secure network, then an end-to-end connection can be created by connecting to the proxy at either side.

VI. CONCLUSION

This paper has described some of the challenges involved in quality of service for wireless networks as well as some solutions which allow service guarantees to be

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made. Several QoS solutions have been presented, including QoS architectures that work with the data link layer. Some solutions have been presented that are specific to a certain aspect of QoS, such as admission control, class adaptation, and routing. Since there are many types of service guarantees that can be made, and a QoS solution must balance the network's ability to satisfy service guarantees with overall network utilization, there are many solutions available that each have their own benefits and trade-offs.

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