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Measurement-driven admission control on wireless backhaul networks

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Abstract

IEEE 802.11 wireless networks perform poorly in the presence of large traffic volumes. Measurements have shown that packet collisions and interference can lead to degraded performance to the extent that users experience unacceptably low throughput, which can ultimately lead to complete network breakdown [12]. An admission control framework that limits network flows can prevent network breakdown and improve the performance of throughput and delay-sensitive multimedia applications. In this paper, we present a measurement-driven admission control scheme that leverages wireless characteristics for intelligent flow control in a static wireless network. Experiments on the 25 node UCSB MeshNet show that the proposed admission control scheme can enhance network performance such that the QoS requirements of real time applications, such as VoIP, can be met.

Keywords: Wireless mesh networks; Admission control

1. Introduction

The deployment and usage of IEEE 802.11 wireless networks for Internet access has increased manyfold in recent years. According to a recent report, the usage of WiFi service (from a single provider) increased by 111% in the short time-span of 10 months [26]. Several cities around the world have announced plans to deploy (or have already deployed) city-wide 802.11-based networks that provide free Internet connectivity. These large networks offer use to thousands of users simultaneously. If the growth in the usage of wireless networks continues along current trends, these networks will soon become overutilized and congested. Unsatisfactory user experiences in city-wide networks have already led to questions about the ability of 802.11-based networks to sustain large traffic volumes [31]. With the growing usage of wireless networks and the increasing bandwidth requirements of current applications, these networks will suffer from increased levels of congestion and eventually breakdown. To study congestion in currently deployed networks, Jardosh et al. present two case studies of operational 802.11 WLANs that experienced network breakdown [12]. These networks, deployed at Internet Engineering Task Force (IETF) meetings, consisted of over 100 access points (APs) with more than 1000 simultaneous users. Measurements showed that frequent packet collisions and interference led to degraded network performance to the extent that users experienced unacceptably low throughput and, in many cases, failed to maintain an association with any AP. The result was sparse or no connectivity for all the users in the network and an eventual network breakdown. The fundamental cause of the problem of congestion and degraded performance is the shared nature of the wireless medium. This problem can also be attributed to the design of the IEEE 802.11 protocol. Nodes in an 802.11-based network contend for access to the same spectrum. This is unlike other wireless networks, such as cellular networks, where the bandwidth required for a flow is reserved during the call-setup phase. Also, the IEEE 802.11 DCF mode employs CSMA/CA-based channel access, which creates the classic hidden terminal and exposed terminal problems. These problems can have a detrimental effect on the network performance.

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Admission control solutions that limit the traffic in 802.11-based wireless networks to sustainable levels can prevent situations of network congestion. Although there has been significant research on admission control for 802.11-based wireless networks, there lacks a realistic system implementation that can limit traffic in these networks. This gap between proposed solutions and their actual deployment is, in many cases, due to the existence of unrealistic assumptions that render a system implementation infeasible. Other admission control solutions require modifications to the hardware. These solutions are not suited for networks that are already deployed. Therefore, there exists a need for an admission control solution that both takes into account the behavior of a real-world 802.11 network and is implementable on commodity off-the-shelf radios.

In this paper, we present measurement-driven admission control (MDAC), a measurement-driven framework for admission control in wireless networks. The framework uses network measurements to characterize the behavior of the wireless channel and continuously measures the availability of resources in the network. The resource availability is measured in the form of the time fraction for which the wireless medium is free. This information is then used in the decision-making process that determines whether to admit new flows into the network.

Our contributions in this paper are twofold. First, we present an analysis of wireless network behavior that is essential to perform admission control. Second, we present the design, implementation and evaluation of an admission control scheme that can intelligently limit the flows in the network, thereby preventing congestion, while at the same time achieving efficient utilization of the wireless medium. The remainder of the paper is organized as follows. Section 2 presents a simple experiment that illustrates the need for an admission control solution. Section 3 lists the assumptions and terminology used in the paper. We present our findings about the characteristics of wireless links in Section 4. Section 5 describes the design of the admission control scheme. We present the details of our implementation and the results from evaluation in Sections 6 and 7, respectively. Section 8 discusses some of the issues and challenges of our scheme. In Section 9 we contrast our work with existing literature and, finally, we conclude in Section 10.

2. Motivational scenario

We perform a simple experiment to understand the extent of deterioration in network performance in the absence of admission control. The experiment also demonstrates the need for an admission control scheme in wireless networks. We first describe the experimental testbed.

2.1. Testbed description

All the experiments described in this paper were conducted in the UCSB MeshNet, an indoor wireless testbed which consists of 25 wireless nodes [30]. All nodes in the testbed use 802.11a/b/g cards based on the Atheros chipset. Several nodes in the testbed have multiple radios. However, in this paper we only use one radio of each node, operating in the 802.11b/g mode. Each node is also equipped with an Ethernet interface that is used to control the node during experiments, thus ensuring that the experiment control traffic does not affect the wireless network experiments. The nodes use Linux (kernel version 2.4) as their operating system. We use the open source MadWifi [28] driver v0.9.2 to control the cards. RTS/CTS is disabled for all the radios. The nodes are placed in different locations on three floors of the building. The testbed coexists with an 802.11b wireless LAN that provides Internet connectivity throughout the building.

2.2. Orchestrating congestion

We create a scenario on the UCSB MeshNet testbed to understand the extent of damage caused by uncontrolled flow admission in the network. We consider the flows in the network to belong to real-time applications such as voice over IP (VoIP), i.e., they are delay-sensitive and have strict throughput requirements. We initiate 15 64 kbps CBR flows that imitate VoIP calls between random node pairs who are in the immediate neighborhood of each other. Each flow lasts for 300 s and the flow arrival rate is one every 10 s. Fig. 1a and b shows the throughput and delay performance of the flows over time.

We make two observations from these graphs. First, the impact on throughput and delay is drastic and we can clearly demarcate the time beyond which the network starts to collapse; the 150 s time on the graphs represents this point. Second, congestion can spread and affect the flow behavior across the entire network. In the scenario shown, the throughput and delay of the flows in the first 150 s of the experiment are within the limits acceptable to the VoIP application. When the twelfth flow is admitted in the network at around 150 s into the experiment, the throughput and delay performance of most of the flows begin to rapidly deteriorate and the ongoing flows no longer receive their needed QoS. It is thus clear that congestion at one point in the network could cause detrimental effects across the entire network.

Therefore, unrestricted flow admission in the network affects the quality of service available to new flows as well as established flows. This observation motivates our design of an admission control scheme to perform intelligent flow control in the network.

3. Assumptions and terminology

In this section, we first describe the attributes of the networks for which we design our admission control scheme. Then, we define some of the common terms used throughout the paper.