UNIVERSITI PUTRA MALAYSIA

WEIGHTED WINDOW FOR TCP FAIR BANDWIDTH ALLOCATION IN WIRELESS LANS

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By

MOJTABA SEYEDZADEGAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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To My Parents . . .

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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FOR TCP FAIR BANDWIDTH ALLOCATION IN WIRELESS LANS

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January 2008

Chairman: **Associate Professor Mohamed Othman, PhD**

Faculty: **Computer Science and Information Technology**

The explosive growth of the Internet has extended to the wireless domain. The number of Internet users and mobile devices with wireless Internet access is continuously increasing. However, the network resource is essentially limited, and fair service is a key issue in bandwidth allocation. The main objective of this research is to provide fair service in terms of throughput among wireless stations using the TCP window size according to Access Point (AP) queue size for fair bandwidth allocation in wireless LANs.

In the first part of this research the focus is on the issue of fairness among stations having different numbers and directions of flow. It is shown in this part that the current WLANs allocate bandwidth unfairly. It is also identified that the cause of this unfairness problem is TCP cumulative ACK mechanism combined with the packet dropping mechanism of AP queue and the irregular space for each station in AP queue.

The proposed method allocates converged bandwidth by introducing weighted window method which adjusts the TCP window size based on the current conditions of the network. Therefore, this method works in wireless nodes without requiring any modification in MAC.

The second part dealt with the fair bandwidth allocation problem for different required bandwidth which aims to improve weighted window method to assure fair channel is fairly shared between wireless nodes in the same class of bandwidth. The proposed class-based weighted window method adjusts the TCP window size of each station according to their weights. So the stations share the wireless channel fairly in terms of throughput.

The proposed methods can guarantee fair service in terms of throughput among wireless users either they require the same or different bandwidth.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBERAT TETINGKAP
UNTUK PERUNTUKAN JALUR LEBAR YANG SAKSAMA DI DALAM RANGKAIAN SETEMPAT TANPA WAYAR**

Oleh

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Januari 2008

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Peningkatan penggunaan Internet yang mendadak mempengaruhi domain penggunaan komunikasi tanpa wayar. Jumlah pengguna Internet dan peralatan bergerak yang dilengkapi dengan akses Internet tanpa wayar semakin bertambah. Walau bagaimanapun, sumber rangkaian adalah terhad, dan perkhidmatan yang saksama adalah isu utama di dalam peruntukan jalur lebar. Objektif utama kajian ini adalah untuk mengkaji daya pemprosesan antara stesen rangkaian tanpa wayar dengan mengungkap saiz tetingkap TCP menurut saiz barisan AP untuk peruntukan jalur lebar yang saksama di dalam rangkaian setempat tanpa wayar.

Fokus di dalam bahagian pertama kajian ini adalah berkenaan isu peruntukan sumber di kalangan stesen-stesen yang mempunyai bilangan dan arah aliran trafik yang berbeza. Di dalam bahagian ini juga, peruntukan jalur lebar yang tidak saksama yang berlaku di dalam rangkaian setempat tanpa wayar pada masa kini diterangkan. Penyebab kepada

masalah ketidaksaksamaan ini adalah kombinasi mekanisma ACK yang bertimbun dengan mekanisma pengguguran barisan AP beserta ruang di dalam barisan AP yang tidak tetap untuk setiap stesen. Kaedah yang dicadangkan memperuntukkan jalur lebar dengan penggunaan teknik pemberat tetingkap dan ia menyesuaikan saiz tetingkap TCP berdasarkan keadaan semasa rangkaian. Oleh itu, kaedah ini berfungsi tanpa memerlukan sebarang pengubahsuaian terhadap MAC.

Bahagian kedua thesis ini adalah berkenaan masalah peruntukan jalur lebar yang saksama untuk keperluan jalur lebar yang berbeza yang mana bertujuan untuk memperbaiki kaedah pemberat tetingkap demi menjamin perkongsian saluran yang saksama di antara nod-nod tanpa wayar yang tergolong di dalam kelas jalur lebar yang sama. Kaedah pemberat tetingkap berdasarkan kelas yang dicadangkan ini mengubahsuai saiz tetingkap TCP untuk setiap stesen berdasarkan pemberat setiap stesen. Oleh itu, stesen-stesen berkongsi saluran tanpa wayar dengan saksama dari segi truput.

Kaedah-kaedah yang dicadangkan menjamin perkidmatan yang saksama dari segi truput untuk semua pengguna tanpa wayar tanpa mengira sama ada mereka memerlukan jumlah jalur lebar yang sama atau tidak.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or other institution.

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MOJTABA SEYEDZADEGAN

Date: May 20, 2008

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LIST OF ABBREVIATIONS

ACK	Acknowledge
AP	Access Point
ATC	Access Time Control
BSS	Basic Service Set
CBR	Constant Bit Rate
CSMA/CA	Carrier Sensing Multiple Access / Collision Avoidance
CTS	Clear to Send
CW	Contention Window
DATC	Distributed Access Time Control
DCA	Downlink Compensation Access
DCF	Distributed Coordination Function
DIFS	Distributed Interframe Space
DS	Distribution System
DSM	Distribution System Medium
ECN	Explicit Congestion Notification
ESS	Extended Service Set
FTP	File Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
IFS	Inter Frame Space
ISN	Initial Sequence Number
ISP	Internet Service Provider
Kbps	Kilo bit per second

KB	Kilo Byte
LAN	Local Area Network
LLC	Logical Link Control
MAC	Media Access Control
Mbps	Mega bit per second
NAM	Network Animator
NS	Network Simulator
OTcl	Object Oriented Tcl
PCF	Point Coordination Function
PDA	Personal Digital Assistance
PIFS	Point Coordination Function Interframe Space
RED	Random Early Detection
RF	Radio Frequency
RTS	Request to Send
RTT	Round Trip delay Time
SIFS	Short Interframe Space
Tcl	Tool Command Language
TCP	Transport Control Protocol
TV	Television
UDP	User Datagram Protocol
VBR	Variable Bit Rate
WBM	Wireless Bandwidth Management
Wi-Fi	Wireless Fidelity
WISP	Wireless Internet Service Provider

WLAN	Wireless Local Area Network
WS	Work Station
WW	Weighted Window method

CHAPTER 1

INTRODUCTION

Data communications and networking are changing the way people live. The goal is to make it possible to exchange data such as text, audio, and video from any point in the world to another; and to access the Internet in order to download and upload information anywhere at anytime. In addition to all mentioned above, sending or receiving e-mails, communicating with others through instant message services, using peer-to-peer applications for sharing files, and enjoying on-line games are also the goals of data communication. It is expected that the Internet continues to grow with many new applications.

Due to continuous growth of the Internet, wireless communication is becoming very popular. Wireless Internet Service Providers (WISPs) implement wireless LAN based on IEEE 802.11 standard [1]. In public areas, these WLAN access networks are also called Wi-Fi hot spots. The number of wireless users has increased explosively. Besides laptop and Personal Digital Assistants (PDAs), many new mobile devices such as cellular phones, portable media player, and portable game devices tend to support Internet connectivity in wireless zones.

However, the current wireless LANs cannot provide any quality guarantee on throughput. In addition fair service among users is one of the most pressing concerns. Especially in a Wi-Fi hot spot where many users share a limited resource, it is imperative to provide fairness in terms of throughput.

This thesis focuses on providing a fair resource allocation mechanism in wireless networks. The first part of this thesis deals with the fairness issue of the stations having different numbers and different directions of flow, while the second part focuses on fairness assurance in different classes of bandwidth.

1.1 Background and Motivation

The WLAN industry has emerged as one of the fastest-growing segments of the communication trade. Due to this growth, being lower in cost, faster and simpler to setup and use in comparison with the previous generation products, WLANs are widely deployed. In order to satisfy user's demand to access the Internet anywhere and anytime, WLAN in the infrastructure mode can provide network access in public areas, such as convention centers, campuses, airports, hotels, etc. As the number of WLAN users has been increasing rapidly, fair service among users has become an important issue. Since most Internet services run over TCP connections, this research focuses on TCP fairness in WLAN.

Many researchers have studied TCP fairness in access networks using the IEEE 802.11 WLAN. They have shown that the reason for unfairness between uplink and downlink flows is packet drops in the AP and it penalizes the downlink flows by the TCP congestion control mechanism. Though, to resolve this unfairness problem, they have proposed some solutions. However, their methods or solutions require the modification of the existing MAC protocol and impractical to apply to the current infrastructure WLANs.

"Moreover, since they did not consider the case when each station has a different number of flows, they cannot provide fairness among stations having a different number of flows"- D. Kim, 2006 [2]. From this point of view, this research proposes methods which can provide per-station fairness and can be implemented without any modification to the MAC layer.

1.1.1 Infrastructure Wireless LANs

"The infrastructure includes the Distribution System Medium (DSM), Access Point (AP), and portal entities. It is also the logical location of distribution and integration service functions of an Extended Service Set (ESS). An infrastructure contains one or more APs and zero or more portals in addition to the Distribution System (DS)"- IEEE Std 802.11-1997 [1].

In IEEE 802.11 [1], MAC protocol is designed to provide equal chance for each station to access the channel. Distributed Coordination Function (DCF) and Point Coordination Function (PCF) are two MAC techniques. The aim of DCF is to give equal access opportunity to all wireless devices and PCF gives more control to an Access Point (AP). While the current Internet utilizes TCP as the transport-layer protocol and IEEE 802.11 infrastructure mode as today's networks, the interaction between DCF and TCP can cause unfairness among the stations. The reason behind this will be discussed latter on.

1.1.2 Fairness

The notion of fairness arises from a situation where many users share a resource and the available resource is limited so that the demands of all users cannot be satisfied sufficiently.

In real networks, users can generate several flows for various applications such as web browsing, chatting, file transferring, sending and receiving e-mail, etc. A greedy user can make many flows and use a large amount of bandwidth capacity. Thus, the other users may use less bandwidth. Since the users expect the same transferring rate and bandwidth for the same payment, Internet Service Provider (ISP) should provide fair service among users. It is desirable that all users can utilize channel capacity equally regardless of the numbers and directions of flow [3].

1.2 Problem Statement

The system studied is a network consisting of wired and wireless nodes. Each node can establish connections with corresponding nodes in both directions (Uplink and Downlink) through an AP.

Whilst DCF is to give equal access opportunity to all wireless devices, uplink stations and AP always participate in the contention to access the channel. Thus the single uplink station has a chance with the probability of one half, and each downlink station has the opportunity to access the channel with the same probability divided between numbers of downlink stations. Accordingly unfairness will occur.

Apart from this, two types of packets are sent to the AP queue: TCP data frames for downlink flows and TCP Acknowledgement (ACK) packets for uplink TCP flows. The main cause of the unfairness is the packet dropping mechanism at the AP queue (as clarified in section 2.2).

Furthermore, bandwidth of up to 11 Mbps for WLAN, which is much smaller than that of wired networks, is the cause of bottleneck among wired and wireless nodes. Traffic congestion at the AP occurs, resulting in packet losses due to queue overflow.

Unlike the wired nodes, mobile stations do not reduce window sizes due to the mechanism of cumulative acknowledgment. For this reason, if uplink and downlink TCP flows coexist, the stations having uplink TCP flows tend to use most of the bandwidth.

The key problem is the irregular space for each station in the AP queue. That is the number of stations and flows per station are disproportionate to the AP queue size.

1.3 Research Objectives

In this research the objectives have been set and can be summarized in the following points:

- To provide fair service *i.e.* throughput for wireless users which have different numbers and directions of flow with the same bandwidth requirement by proposing a new method.