UNIVERSITI PUTRA MALAYSIA

QUALITY OF SERVICE-BASED MEDIUM ACCESS CONTROL MECHANISM FOR MULTIMEDIA TRAFFIC IN MOBILE *AD HOC* NETWORKS

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MASTER OF SCIENCE
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By

MUBARAK ABDALLAH JAMA

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

June 2009

Dedicated to

My loving parents,

my sisters and my brother

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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June 2009

Chairman: Borhanuddin Bin Mohd Ali, PhD

Faculty: Engineering

This thesis describes an investigation on the problem of quality of service (QoS) support in mobile ad hoc networks (MANETs). The decentralized nature of wireless ad hoc networks makes them suitable for a variety of applications where central nodes cannot be relied on. This thesis presents a medium access control (MAC) QoS mechanism for multimedia applications in IEEE 802.11e based MANETs. IEEE 802.11e standard draft includes new features to facilitate and promote the provision of QoS guarantees in wireless networks with a long-term solution based on QoS-architectures. The motivation is driven by the need to support increasing demand of time-sensitive applications such as Voice over IP (VoIP) and video conferencing applications.

IEEE 802.11e enhances the Distributed Coordination Function (DCF) and the Point Coordination Function (PCF) of the legacy IEEE 802.11, through a new coordination function: the Hybrid Coordination Function (HCF). Within the HCF, there are two methods of channel access: HCF Controlled Channel Access (HCCA) and Enhanced

Distributed Channel Access (EDCA). EDCA operates in infrastructure-less ad hoc mode and is widely used in MANETs, unlike HCCA, which further assures QoS provisioning operates in infrastructure mode in the presence of access points (AP). Recent researches showed that EDCA lacks QoS support of real-time traffic in MANETs due to its contention based medium access method.

This thesis takes HCCA QoS provisioning potentials to MANETs by implementing a MAC mechanism in which HCCA is employed on top of EDCA to work in infrastructure-less environment like MANET with the help of multiple channels. The mechanism dedicates a unique receiver-based channel to every mobile node. It will act as virtual hybrid coordinator (VHC) to exercise control over the channel in contention-free manner while maintaining a common channel in which all mobile nodes can exchange broadcast and routing related messages.

The mechanism can be easily integrated with existing 802.11 systems without modification to existing protocols while ensuring a level of admission control and resource reservation over the medium. Simulation results indicate that the mechanism significantly improves the overall network throughput by 20% at the saturation point and improves average delay by 20% at the saturation point compared to pure EDCA with or without multiple channels. Even with multi-channel EDCA, our mechanism guarantees better performance in terms of throughput and MAC delay for high priority traffic in MANET. The research contribution on MAC layer can be integrated into a larger framework for QoS support in MANETs, which opens a wide range of further research in QoS provisioning in MANETs and solve QoS multi-layer design and implementation issues.

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

KUALITI PERKHIDMATAN MEKANISMA MAC DALAM TRAFIK MULTIMEDIA DALAM JARINGAN *AD HOC* MUDAH ALIH

Oleh

MUBARAK ABDALLAH JAMA

Jun 2009

Pengerusi : Borhanuddin Bin Mohd Ali, PhD

Fakulti : Kejuruteraan

Tesis ini mengkaji masalah kualiti perkhidmatan (QoS) dalam jaringan ad hoc mudah alih (MANETs) iaitu sejenis reka bentuk jaringan yang dicirikan oleh topologi dinamiknya dan kekurangan sumbernya. Ia membekalkan suatu mekanisma QoS kawalan capaian media (MAC) untuk aplikasi multimedia di dalam MANET berdasarkan IEEE 802.11e. Pelan piawai IEEE 802.11e mempunyai ciri-ciri baru untuk memudahkan dan mendorong pelaksanaan jaminan QoS di dalam jaringan tanpa wayar dengan penyelesaian jangka masa panjang berasaskan reka bentuk QoS. Motivasi ini berdasarkandidorong oleh keperluan untuk menyokong permintaan untuk aplikasi yang sensitif terhadap masa seperti Voice over IP (VoIP) dan aplikasi persidangan video.

IEEE 802.11e meningatkan prestasi Fungsi Koordinasi Tertabur (DCF) dan Fungsi Koordinasi Titik (PCF) daripada IEEE 802.11 melalui fungsi koordinasi yang baru iaitu: Fungsi Koordinasi Hibrid (HCF) dalam HKF, dan terdapat juga dua kaedah akses saluran iaitu: Akses Saluran Terkawal HKF (HCCA) dan Akses Saluran

Tertabur Tertingkat (EDCA). EDCA beroperasi dalam mod ad hoc dan tiada infrastruktur yang digunakan secara meluas di dalam MANET: perkara ini berbeza dengan ASTH, kerana ASTH memastikan sokongan QoS beroperasi dalam mod berinfrastruktur dengan adanya titik akses. Penyelidikan kini menunjukkan bahawa EDCA tiada sokongan QoS untuk trafik semasa di dalam MANETs dan ini disebabkan oleh masalah dalam kaedah akses medianya yang berkonflik.

Penyelidikan ini mengambil HCCA QoS sebagai sokongan dan usaha kepada MANET dengan mengaplikasikan satu mekanisma MAC di mana HCCA digunakan bersama dengan EDCA dalam keadaan tiada infrastruktur dengan bantuan multi-saluran. Mekanisma ini menyediakan satu saluran unik yang bergantung kepada penerima bagi setiap nodus mudah alih. Ia akan bertindak sebagai pengkoordinasi hibrid virtual untuk mengawal saluran dalam cara yang tidak berkonflik, dan pada masa yang sama mengekalkan satu saluran umum, di mana semua nodus mudah alih mampu menukar ganti mesej penyiaran atau yang berkaitan dengan routing.

Mekanisma ini boleh diintegrasikan dalam sistem 802.11 yang sedia ada dengan mudah, tanpa mengubahsuaikan protokol yang sedia ada. Pada masa yang sama, ia memastikan terdapatnya kawalan terhadap kemasukan dan sumber tempahan di dalam saluran. Hasil simulasi menunjukkan bahawa mekanisma ini memperbaiki lagi keseluruhan jaringan dan kelewatan menghantar data, berbanding dengan EDCA, tidak kira dengan adanya atau tiadanya multi-saluran.

Penyumbangan kajian ini ke atas lapisan MAC boleh diintegrasikan dalam rangka yang lebih besar untuk sokongan QoS di dalam MANETs. Ini meluaskan lagi

peluang untuk kajian yang lain lebih lanjut dengan sokongan QoS di dalam MANETs, dan menyelesaikan isu-isu reka bentuk QoS yang multi-lapisan serta penggunaannya.

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In the name of Allah, the most Merciful, Gracious and most Compassionate, Creator of all knowledge for eternity. We beg for peace and blessing upon our Master the beloved Prophet Mohammed (Peace and Blessing be Upon Him) and his progeny, companions and followers.

I wish to extend my deepest appreciation and gratitude to Islamic Development Bank (IDB) for sponsoring me to pursue my higher studies by granting me M.Sc. scholarship. Without IDB Scholarship I wouldn't be able to achieve my dream, thanks a lot.

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I certify that an Examination Committee has met on 23 June 2009 to conduct the final examination of Mubarak Abdallah Jama on his thesis entitles "QUALITY OF SERVICE MACHANISM FOR MULITIMEDIA TRAFFIC IN MOBILE ADHOC NETWORKS (MANETs)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis 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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Date: 11 February 2010

DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any degree at UPM or other institution.

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MUBARAK ABDALLAH JAMA

Date: 10th December 2009

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LIST OF ABBREVIATIONS

ACK	Acknowledgement
AP	Access Point
AReq	Association Request
ARes	Association Response
CBR	Constant Bit Rate
CFP	Contention Free Period
CP	Contention Period
CSMA	Carrier Sense Multiple Access
CSMA-CD	Carrier Sense Multiple Access with Collision Detection
CW	Contention Window
DCF	Distributed Coordination Function
DiffServ	Differentiated Services
DIFS	Distributed Coordination Function IFS
EDCA	Enhanced Distributed Channel Access
FTP	File Transfer Protocol
HCCA	HCF Controlled Channel Access
HCF	Hybrid Coordination Function
IFS	Inter-Frame Space

IntServ	Integrated Services
ITU - T	International Telecommunication Union – Telecommunication
MAC	Medium Access Control
MANET	Mobile Ad hoc NETworks
MN	Mobile Node
PCF	Point Coordination Function
QoS	Quality of Service
RIFS	Reservation IFS
VHC	Virtual Hybrid Coordinator
VoIP	Voice over IP
WLAN	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Background

The ability to communicate with anyone from anywhere on the planet has been mankind's dream for a long time. Wireless networks are the only key to enable such unwired communication. However, with the recent technological advances, coupled with the demand for flexibility and mobility of wireless systems, the development of "anywhere and anytime" concept of mobile ad hoc networking becomes a reality. Mobile ad hoc networks (MANETs) have the potential to serve as the basic building blocks of the future ubiquitous communication and computing systems, capable of interconnecting thousands of heterogeneous devices. As their popularity increases day-by-day, the mobile ad hoc network (MANET) working group was charted in 1997 in order to discuss and develop solutions in this area. The MANET working group defines a mobile ad hoc network as an autonomous system of mobile routers (and associated hosts) connected by wireless links – the unions of which form an arbitrary graph (MANET WG).

The nodes in an ad hoc network can dynamically join and leave the network frequently, often without warning and possibly with interruption to other nodes' communications. Typically, this type of networks may operate in standalone fashion without necessitating any fixed infrastructure, or may be connected to the global Internet.

The absence of fixed infrastructure in MANETs requires individual nodes be responsible for dynamically discovering which other mobile nodes they can directly communicate with. In this respect, an ad hoc network can be considered to be a peer-to-peer network allowing direct communication between any two nodes as long as they are within the transmission range of each other, provided that adequate transmission energy and desired radio propagation conditions exist at and between the considered node-pair. Such communication between arbitrary end-points often requires routing over multiple-hop wireless paths. In this context, each mobile node can act as end terminal node (terminode) and/or forwarding (transit) node (Blazevic et. al 2001).

Ad hoc networks are thus self-creating, self-organising and self-administrating. They thence offer unique benefits and versatility for a variety of situations and applications. Because of the abovementioned reasons, this kind of network is expected to play important role in future commercial and military applications, where mobile access to wired network is either ineffective or impossible. A few potential examples include soldiers in a hostile environment, fast establishment of communication infrastructure during law enforcement operations, setting up communication in exhibitions, conferences, or sales presentations, operation of wall-free (virtual) classrooms, connecting sensors scattered for biological detection, rare animal tracking, space exploration, undersea operations, and temporary offices such as campaign headquarters. In addition, home or small-office networking and collaborative computing with laptop computers in small areas have recently emerged as other major areas of potential commercial applications.

However, despite their uniqueness, ad hoc networks pose numerous challenges and generate new research problems when compared to fixed wireless networks. This will be discussed in further detail in the following chapter.

This thesis aims to contribute to the area of QoS provisioning IEEE 802.11e based MANETs. First, it provides a basic analysis of the problems caused by the lack of QoS mechanisms in the current MANETs. Second, a study on existing differentiation mechanisms for IEEE 802.11 protocols that explores their usability and importance for voice and video applications are presented. Next, the thesis introduces a MAC QoS provisioning mechanism which has built-in support for service guarantee for multimedia voice and video applications. Finally, the performance of the developed mechanism evaluated in simulation experiments compared to EDCA, the prevalent MAC protocol in MANETs.

1.2 Scope

This thesis focuses on the improvement of QoS provisioning at MAC layer of TCP/IP network model in the context of MANET. The main focus is on the operation of HCCA polling scheme and its setup on top of multi channel medium. This research combines the operations of EDCA and HCCA to form a new 802.11e mechanism to provide a QoS support for real-time application in MANET.

Other QoS building blocks as queuing, scheduling and congestion avoidance are outside the scope of this work.

Figure 1.1 shows the research chart of this thesis. This thesis studies the QoS challenges from the MAC layer perspective. The chart starts with defining the network environment/topology to be studied i.e. MANET. The chart further defines the OSI standard model layer to be researched and modified which is the MAC layer. Then it describes the methodology layer of the research by trying to identify and choose the method and the wireless technology to further improve or modify. It was shown in figure 1.1 that combined EDCF/HCCA operation has been chosen as our operating protocol at MAC layer. While EDCF is sufficient for best-effort traffic, HCCA is required to ensure better resource allocation for voice and video traffic. Another choice made is to use multi-channel instead of the common single channel medium.

Earlier researches showed that the use of a single radio contention-based medium is not suitable for multimedia traffic in multihop MANETs as the network performance degrades when the network size increases and fails to meet the increased throughput and delay requirements of new applications, hence the choice of multiple channels was made. The methodology imports the QoS features in 802.11e into MANET and adds resource reservation and admission control mechanism to maintain fairness. The system analyzed by simulation using NS-2 targeting improvements in two parameters namely throughput and MAC-delay (Kyasanur 2005) (Raniwala 2005).

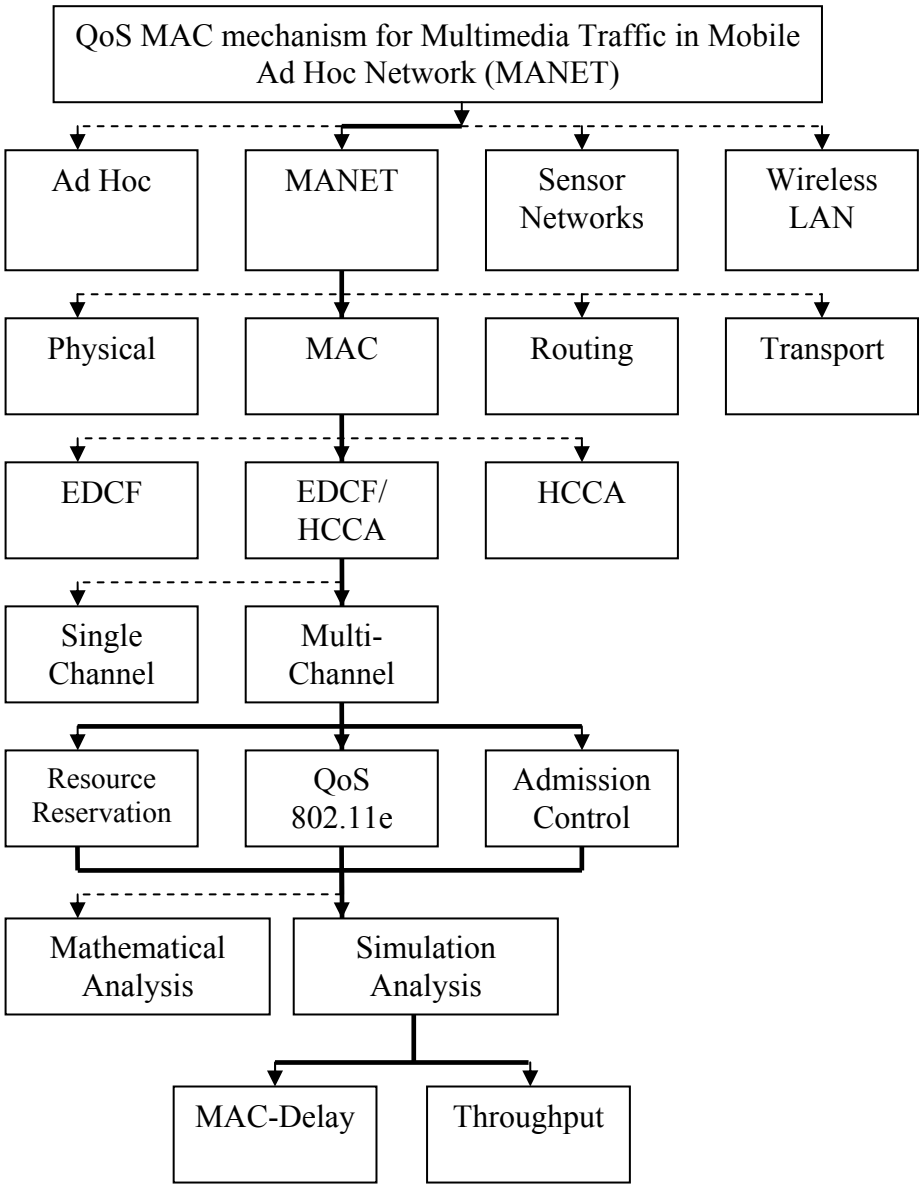

Figure 1.1: The Research Chart

1.3 Motivation

The basic challenge to overcome when dealing with a shared transmission medium is how to control access to the communication channel. Medium access control (MAC) provides this functionality, and therefore defines the rules for orderly access to the shared medium. In this process, MAC plays a crucial role in the efficient and fair sharing of the common communication medium and hence in the QoS provisioning.