ANALYSIS AND SIMULATION OF WIRELESS AD-HOC NETWORK ROUTING PROTOCOLS

By

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
In partial fulfilment of the requirements for the Degree of Master of Science**

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DEDICATION

To my parents

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

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April 2004

Chairman: Professor Borhanuddin Mohd Ali, Ph.D.

Faculty: Engineering

An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. Ad-hoc networks, characterized by dynamic topology. Each host moves in an arbitrary manner and routes are subject to frequent disconnection. During the period of route reconstruction, packets can be dropped. The loss of packets will cause significant throughput degradation. A number of routing protocols like Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector Routing (AODV) and Destination-Sequenced Distance-Vector (DSDV. have been implemented. In this project an attempt has been made using network simulator (NS) to compare the performance of two on-demand *reactive* routing protocols for mobile ad hoc networks: DSR and AODV, along with the traditional *proactive* DSDV protocol, using more stressful parameters, such as a very high mobility, large number of nodes and with a very heavy traffic loads.The simulation results show that at a small to medium field area with a considerably large number of nodes, the table-driven DSDV protocol performs better than the On-demand protocols, AODV and

DSR at low mobility.While On-demand protocols, AODV perform very well at all network conditions. While at large field area all the routing protocols performed poorly due to large number of hops that needed for one node to communicate with another and link breakage are likely to happens. Although DSR and AODV share similar on-demand behavior, the differences in the protocol mechanics can lead to significant performance differentials. The performance differentials are analyzed using varying network load, mobility, and network size. The simulation results show that On-demand routing protocol AODV and Table-driven routing protocol DSDV can be used for most of ad-hoc applications delivering about 95% of data packets to the destination nodes. These simulations are carried out based on the Rice Monarch Project that has made substantial extensions to the NS-2 network simulator to run ad hoc simulations.

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

ANALISIS DAN SIMULASI PROTOKOL PENGHALAAN RANGKAIAN TANPA WAYAR AD-HOC

Oleh

ABDEL HAIMID BASHIR MOHAMED

April 2004

Pengerusi: **Profesor Borhanuddin Mohd Ali, Ph.D.**

Fakulti: **Kejuruteraan**

Rangkaian bergerak tanpa infrastruktur (MANET) adalah suatu kumpulan nod bergerak tanpa wayar yang membentuk rangkaian sementara secara dinamik tanpa penyelenggaraan terpusat. MANET mempunyai ciri utama iaitu topologi rangkaian yang dinamik. Setiap hos bergerak di dalam lakuan yang tidak tetap dan penghalaan selalu terputus. Semasa tempoh pembinaan semula penghalaan, paket-paket boleh dilepaskan. Pelepasan paket-paket tersebut boleh menyebabkan lebarjalur berkurangan. Beberapa protokol penghalaan telah dicipta seperti DSR, AODV dan DSDV. Projek ini ingin membandingkan prestasi protokol penghalaan jenis reaktif seperti DSR dan AODV dengan pro-aktif seperti DSDV. Pembandingan prestasi adalah berdasarkan parameter-parameter rekabentuk seperti kepantasan pergerakan, jumlah nod dan bebanan. Keputusan simulasi menunjukkan bahawa pada lapangan kecil hingga sederhana dengan jumlah nod yang banyak, protokol penghalaan pro-aktif iaitu DSDV mempunyai prestasi yang terbaik manakala protokol penghalaan reaktif iaitu DSR dan AODV mempunyai prestasi lebih baik pada pergerakan terbatas.

Protokol penghalaan AODV pula mempunyai prestasi yang baik pada semua keadaan rangkaian. Pada lapangan yang besar semua protokol penghalaan mempunyai prestasi yang buruk kerana banyak loncatan diperlukan ke sesuatu destinasi dan sambungan terputus menjadi bertambah lazim. Walaupun DSR dan AODV mempunyai jenis penghalaan reaktif, perbezaan pada segi mekanik protokol boleh menyebabkan perbezaan daripada segi prestasi yang ketara. Perbezaan adalah di analisa dengan menggunakan parameter-parameter prestasi seperti peratusan nisbah penghantaran paket, beban penghalaan dan lengah. Keputusan simulasi menunjukkan protokol penghalaan reaktif AODV dan pro-aktif. DSDV boleh digunakan pada kebanyakan aplikasi rangkaian MANET dengan peratusan penghantaran sebanyak 95% ke nod destinasi. Simulasi ini adalah. berdasarkan Projek Monarch Universiti Rice yang telah melakukan penambahan.kepada perisian simulasi rangkaian NS-2 untuk membolehkan simulasi MANET dilakukan.

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I certify that an Examination Committee met on 22nd April 2004 to conduct the final examination of Abdel Haimid Bashir Mohamed on his Master of Science thesis entitled "Analysis and Simulation of wireless Ad-Hoc Network Routing Protocols" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

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

ABDEL HAIMID BASHIR MOHAMED

Date:

22/

11/2003

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LIST OF ABBREVIATIONS

ABR	Associativity Based Routing
AODV	Ad-hoc On-demand Distance Vector Routing
ARP	Address Resolution Protocol
AGT	Agent
BRP	Border routing protocol
CBR	Constant Bit Rate
CBRB	Cluster Based Routing Protocol
CGSR	Cluster Gateway Switching Routing
CMU	Carnegie Mellon University
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access Collision Avoidance
DCF	Distributed Coordination Function
DSDV	Destination Sequence Distance Vector
DSR	Dynamic Source Routing
FSR	Fishy state routing
HYP	Hybrid protocol
IARP	Intra Zone Routing Protrocol
IERP	Inter Zone Routing Protrocol
IFQ	Interface Queue
IMEP	Internet MANET Encapsulation Protocol
IP	Internet Protocol
LANMARK	Landmark Routing Protocol
LCC	Least Cluster Change
LL	Link Layer
LORA	Least Overhead Routing Approach
LSU	Link State Updates
MAC	Media Access Control
MANET	Mobile Ad Hoc Network
NAM	Network Animator
NS2	Network Simulator
ORA	Optimal Routing Approach
OTCL	Object Tool Command Language
PDA	Personal Digital Assistant
QoS	Quality of service
RIP	Router Internet protocol
RTR	Router
RERR	Route Error
RREQ	Routing Request
RREP	route Reply
STAR	Source Tree Adaptive Routing
TCP	Transmission Control Protocol
TORA	Temporally Ordered Routing Algorithm
TBRPF	Topology Broadcast Based on Reverse Path Forwarding
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol

CHAPTER 1

INTRODUCTION

1.1 Background

Wireless networks are emerging new technology that will allow users to access information and services electronically, regardless of their geographic location. Wireless communication between mobile users is becoming more popular ever than before. This is due to proliferation in laptop computers and wireless data communication services, such as wireless modems and wireless LANs. This has led to lower prices and higher data rates, which are the two main reasons why mobile computing continues to enjoy rapid growth. There are two distinct approaches for enabling wireless communication between two hosts.

The first approach is to let the cellular network infrastructure to carry data as well as voice. The major problem with this approach is to handle hands-off, without noticeable delay or packet loss. The other problem is that networks based on the cellular infrastructure are limited to places where there exists such a cellular infrastructure.

The second approach is to form an Ad-Hoc network among all users wanting to communicate with each other. This means that all users participating in the Ad-Hoc network must be willing to forward data packets to make sure that the packets are delivered from source to destination. This form of networking is limited in range by the individual nodes transmission ranges and is typically smaller compared to the range of cellular systems. This does not mean that the cellular approach is better than the Ad-Hoc approach. Ad-Hoc networks have several advantages compared to traditional cellular systems. These advantages include:

On demand setup

Fault tolerance

Unconstrained connectivity.

Ad-Hoc network does not rely on any pre-established infrastructure and can therefore be deployed in places with no infrastructure. This is useful in disaster recovery situation and places with non-existent or damaged communication infrastructure where rapid deployment of communication network is needed. Ad-Hoc network can also be useful in conferences between people where participants can form a temporary network without engaging the services of any pre-existing network. Because nodes are forwarding packets for each other, some sort of routing protocol is necessary to make the routing decisions.

1.2 Wireless Ad-Hoc Networks

A wireless Ad-Hoc network is a collection of mobile/semi mobile nodes with no pre-established infrastructure forming a temporary network. Each of the node has a wireless interface and communicate with each other over either radio or infrared media. Laptop computers and personal digital assistances (PDAs) that communicate directly with each other are some example of nodes in an Ad-Hoc network. Nodes in the Ad-Hoc network are often mobile, but can also consist of stationary nodes, such as access points to the Internet. Semi-mobile nodes can be used to deploy relay points in areas where relay points might be needed temporarily Figure 1.1, shows a simple Ad-Hoc network with three nodes. The outer-most nodes are not within transmitter range of each other. However the middle node can be used to forward packets between the outer-most nodes. With the middle node acting as a router, the three nodes have formed an Ad- Hoc network.

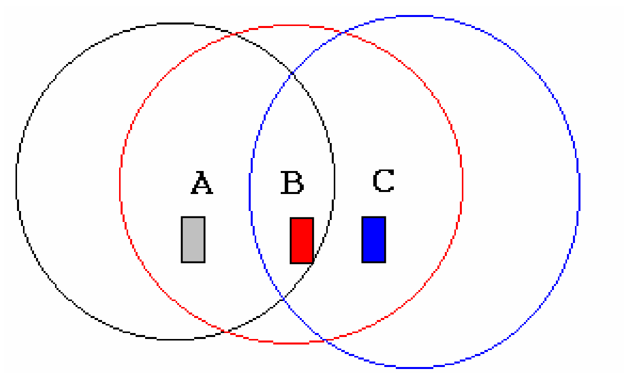

Figure 1.1,: Example of a simple Ad-hoc network with three participating nodes [4].

In Ad-hoc wireless networks, there exists no base stations and each mobile host is smart enough to act as a router to forward packets from one to the other until the packet reaches its destination. The intelligent communications software enable these mobile computers and devices to establish and disestablish networks on the fly, in real time.

Ad-hoc networks are highly dynamic in nature since they can form and deform quickly, without the need for any infrastructure setup and system administration. They can be deployed anytime and anywhere (indoors and outdoors), be it at battlefields or conference rooms.

An Ad-Hoc network uses no centralized administration. This is to ensure that the network will not collapse just because one of the mobile nodes moves out of the transmission range of the others. Nodes should be able to enter/leave the network as they wish. Because of the limited transmitter range of the nodes, multiple hops may be needed to reach other nodes. Every node wishing to participate in an Ad-Hoc network must be willing to forward packets for other nodes. Thus every node acts both as a host and as a router.

A node can be viewed as abstract entity consisting of a router and set of mobile hosts A router is an entity, which, among other things runs a routing protocol. A mobile host is simply an IP-addressable host/entity in the traditional sense.

Ad-Hoc networks are also capable of handling topology changes and malfunctions in nodes. It is fixed through network reconfiguration. For instance if a node leaves the network and causes link breakages delay, both the network will still be operational.

Wireless Ad-Hoc networks take advantage of the nature of the wireless communication medium. In other words in a wired network the physical cabling is done a prior; thus restricting the connection topology of the nodes. This type of restriction is not present in the wireless domain as provided that the two nodes are within transmitter range of each other, an instantaneous link between them may be formed.

1.3 Characteristics of Ad-Hoc Networks

Mobile Ad-hoc networking (MANET) [**2**] is often characterized by a dynamic topology due to the fact that nodes change their physical location by moving around. This favors routing protocols that dynamically discover routers over conventional routing algorithm like distance vector and link state. Another characteristic is that a host/node have very limited CPU capacity, storage capacity, battery power and bandwidth. This means that the power usage must be limited thus leading to a limited transmitter range. The access media, the radio environment, also has special characteristics that must be considered when designing protocols for Ad-Hoc networks. Multi-hop in a radio environment may result in an overall transmit capacity gain and power gain due to the squared relation between coverage and required output power. However by using multi hop, nodes can transmit the packets with a much lower output power.

Ad-hoc networks consist of nodes that are free to move about arbitrarily **[3]**. Nodes are equipped with wireless transmitters and receivers using antennas that may be omni-directional (broadcast), highly directional (point-to-point), possibly steerable, or some combination thereof. Ad-hoc networks have several characteristics:

Dynamic topologies: Nodes are free to move arbitrarily; thus the network topology may change randomly and rapidly at unpredictable times, and may consist of both bi-directional and unidirectional links.

Bandwidth-constrained, variable capacity links: Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In addition, the throughput obtained out of wireless communications after accounting for the effects of multiple access, fading, noise, and interference conditions, etc. Is often much less than a radio's maximum transmission rate. One effect of the relatively low to moderate link capacities is that congestion is typically the norm rather than the exception, i.e. aggregate application demand will likely approach or exceed network capacity frequently. As the mobile network is often simply an extension of the fixed network infrastructure, mobile ad hoc users will demand similar services. These demands will continue to increase as multimedia computing and collaborative networking applications rise.

Energy-constrained operation: Some or all of the nodes in a ad-hoc network may rely on batteries or other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.

Limited physical security: Mobile wireless networks are generally more prone to physical security threats than are fixed-cable networks. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. As a benefit, the decentralized nature of network control in ad-hoc networks provides additional robustness against the single points of failure typical to more centralized approaches.

Ad-hoc networks routing protocol should be designed with the above characteristics in mind. Other desirable properties of Ad-hoc networks routing protocol are:

distributed operation, loop free routes, unidirectional link support, scalability in terms of the number of mobile nodes, and quality of service.

1.4 Usage of Ad-hoc Networks

There is no clear picture of what these kinds of network will be used for, the suggestion vary from document sharing at conferences to infrastructure enhancement and military applications. In areas where no infrastructure such as Internet is available an Ad-Hoc network could be used by a group of wireless mobile hosts. This can be the case in areas where a network infrastructure may be undesirable due to reasons such as cost or convenience. Example for such situation includes disaster recovery personnel or military troupes in cases where the normal infrastructure is either unavailable or destroyed. Other examples include business associates wishing to share files in an airport terminal, or class of students needing to interact during a lecture. If each mobile host wishing to communicate is equipped with a wireless local area network interface, the group of mobile hosts may form an Ad-Hoc network.Access to the Internet and access to resources in networks such as printers are features that probably also will be supported.