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INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

PERFORMANCE STUDY OF MULTICAST ROUTING PROTOCOL OVER MANET

BY

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ABSTRACT

Multicasting is intended for group-oriented communication services. One particularly challenging environment for multicast is a mobile ad-hoc network (MANET) where, the network topology can change randomly and rapidly, at unpredictable times. As a result, several specific multicast routing protocols for MANET have been proposed. Multicast approaches can generally be categorized into two: Proactive and On-Demand. The proactive approach pre-computes and maintains routes to all nodes, including nodes to which no packets are being sent. The on-demand approach creates the routes between nodes that are solely determined when they are explicitly needed to route packets. Multicasting protocols can also be categorized based on the structure used to forward multicast packets which are tree and mesh-based. The uses of on-demand routing approaches have been shown to have significant benefits in terms of reducing the routing protocol's overhead. Therefore, this thesis focuses on performance of on-demand multicast routing protocols over MANET. More specifically, our concern is to characterize the merits of tree and mesh-based on-demand protocols over various ranges of MANET scenarios based on representative performance metrics. As a result, we are able to investigate the relative strengths, weaknesses and applicability of each protocol to diverse situation. For that reason, we particularly concentrate on NS-2 simulation of three protocols: MAODV, ODMRP and ADMR protocol. These protocols are the prominent on-demand multicast routing protocols in MANET as well as represent the tree and mesh-based protocols. Through simulation we demonstrate that though all these three protocols share similar on-demand behavior, the differences in routing structure leads to performance differentials. Based on evaluation, we make recommendation for the performance improvement of ODMRP protocol.

ملخص البحث

التراسل المتعدد أعد لأجل خدمات الاتصال لفريق التوجيه. أحد أهم التحديات البيئية بشكل خاص للتراسل هو شبكة Ad-hoc (MANET) حيث أن طوبولوجيا الشبكة يمكن أن تتغ بسرعة، بشكل عشوائي و الأوقات المستقلبة. كنتيجة لذلك اقترحت عدة مسارات دد مراسيم التراسل (MANET). طرق التوزيع عموماً كن تصنيفها إ قسم : مترقب وعلى طلب. طريقة المترقب سب مسبقاً، و افظ على المسارات لكل الأقطاب، يتضمن ذلك الأقطاب ال لا ترسل منها رزم. طريقة على طلب لق مسار ب الأقطاب ال تقدر فقط م تاجون توجيه الرزم بشكل صريح. مراسيم التوزيع كن أيضاً أن تصنف استناداً إ التركيبة المستعملة لإرسال الرزمة ال هي عبارة أو على شكل شجرة وشباكة قاعدية. استعمال طريقة التوجيه عن طلب أظهرت لتكون ا منافع مهمة من ناحية فيض نظام فوق التوجيه. لذا تركز هذه الأطروحة على أداء نظام توجيه الموزع على طلب من جانب (MANET). بصورة أكثر ديداً، ما يهمنا هو ديد خصائص، ومزايا الشجرة والشبكة القاعدية لنظام التراسل (على طلب) على امتدادات متعددة وسيناريوهات (MANET) مستندة على مصفوفات الأداء التمثيلي. كنتيجة، ن قادرين على قيق نسب مواطن القوة والضعف وقابلية تطبيق المراسيم على حالات متنوعة. ذا السبب، ركزنا بشكل خاص على ا اكات NS-2 للمراسيم الثلاث MAODV، ODMRP وADMR. هذه الأنظمة هي الأبرز مسارات التراسل عند الطلب (MANET)، كذلك ثل مراسيم الشجرة والشبكة القاعدية. من خلال ا اكاة تظهر أنه بالرغم من كل هذه الثلاث مراسيم المشتركة السلوك عند الطلب إلا أن الاختلاف هيكل التوجيه يؤدي إ الفرق الأداء . استناداً إ التقييم، نعمل توصية لتحس أداء مراسيم (ODMRP).

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Computer and Information Engineering.

Farhat Anwar
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Computer and Information Engineering.

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Examiner (Internal)

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Ahmad Faris Ismail
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Zeldi Suryady

Signature:……………………… Date: ……………………

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LIST OF ABBREVIATIONS

A.B.A.M	Associativity Based Ad-hoc Multicast
A.D.M.R	Adaptive Demand-Driven Multicast Routing
AMRoute	Ad-hoc Multicast Routing Protocol
A.M.R.I.S	Ad-hoc Multicast Routing with increasing id-numbers
A.O.D.V	Ad-hoc On-demand Distance Vector
C.A.M.P	Core-Assisted Mesh Protocol
C.B.T	Core Based Tree
D.A.G	Directed Acyclic Graph
D.V.M.R.P	Distance Vector Multicast Routing Protocol
F.G.M.P	Forwarding Group Multicast Protocol
L.A.M	Lightweight Adaptive Multicast
M.A.O.D.V	Multicast Ad-hoc On-Demand Vector
MANET	Mobile Ad-hoc Networks
N.S.M.P	Neighbor Supporting Ad-hoc Multicast Routing Protocol
O.D.M.R.P	On-Demand Multicast Routing Protocol
PIM-DM	Protocol Independent Multicast – Dense Mode
PIM-SM	Protocol Independent Multicast – Sparse Mode
QoS	Quality of Service
R.P	Rendezvous Point
R.P.F	Reverse Path Forwarding
T.O.R.A	Temporally Ordered Routing Algorithm

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

With the increasing affordability of laptop computers and wireless data communication devices, wireless communication between mobile users are becoming more and more popular, sometimes, when there is no communication infrastructure such as base stations and mobile switching centers that make up today's cellular network or the existing infrastructure is expensive or inconvenient to use, people can setup networks of their own on the fly. Which are so called "Ad-hoc Networks".

Formally, Chlamtac, Conti and Liu (2003) asserted a definition of a mobile ad-hoc network (MANET) as a transient network formed dynamically by a collection of (arbitrary located) autonomous wireless mobile nodes without the use of existing network infrastructure, or centralized administration. The nodes are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Moreover, each mobile node has a limited transmission range. So, these nature of mobile nodes decide the characteristics of MANET such as dynamic topology, low bandwidth, high packet loss and power constraints, etc (Kaliaperumal and Jeyakumar, 2005).

In general, routes between nodes in ad-hoc network may include multiple hops. Since each node has limited transmission range, not all data can reach all the intended hosts directly. Hence, for communicating with nodes that reside within the transmission range, they can communicate directly. On the other hand, for communicating with nodes that reside beyond the transmission range, a source to destination path could be relayed hop by hop through several intermediate nodes (multi-hop paths). So, each node is also acts as a router. Thus, the ad-hoc routing protocols play important responsibility to find such paths and for detecting broken links.

Multicast routing appears to be a key issue in ad-hoc networks, since there are more and more ad-hoc applications where one-to-many dissemination is necessary. The problem of multicast routing in ad-hoc environment is born out of achieving multicast capability in scenario where all the nodes interested in participating in multicast group are not within the transmission range of the sender (Viswanath, Obraczka and Tsudik., 2006). For that reason, setting up and maintaining a multicast communication infrastructure may be difficult and costly. There is a need to have some mechanisms to forward multicast traffic through the entire multi-hop network, based on group member information. Therefore, multicast routing protocols plays an important role within this network. It can reduce the communication costs by sending the same data to multiple recipients and minimizes the link bandwidth consumption; sender and router processing and delivery delay (Viswanath et al, 2006).

In the traditional wire-line environment, the basic approach adopted for multicasting consists of establishing a routing tree for a group of routing nodes that constitutes the multicast session. When the routing tree is established a packet sent to all nodes in the tree traverses each node and each link in the tree only once.

Due to the inherent characteristics of MANET, multicast routing protocols for wired network such as Core Based Tree (CBT) (Ballardie, Francis and Crowcroft., 1993) and Distance Vector Multicast Routing Protocol (DVMRP) (Pusateri, 2000) are not suitable for MANET since there is no fixed home agent to serve as routing reference. Besides that, in MANET the topology of network is frequently changing due to few factors. Amongst the important factor are, the nodes are mobile, the free reorganization from these conventional multicast protocol can cause significant signaling overhead and loss of data packet frequently (Murthy and Manoj, 2004).

Therefore, numbers of multicast protocols are proposed for ad-hoc environment. These protocols are commonly classified as being either proactive or reactive. Protocols based on *proactive (also called table-driven)* approach try to keep up-to-date routing information periodically, regardless of whether this information is currently needed for communication. To maintain such routes, the network suffers from periodic control packet flood, which can take a large portion of limited bandwidth. Yet, it offers simplicity of design, and minimizes the latency for data transmission, as the route is always available before communication begins. Protocols based on reactive (*also called on-demand)* approach only discover the routes between nodes that wish to communicate. So they generate less routing update control overhead, thus increasing bandwidth utilization. However, the source node must wait for route discovery before sending data packets, which increases latency.

1.2 PROBLEM STATEMENT

Due to the quick and economical deployment of ad-hoc networks, they can be applied in several areas. They have been firstly used in military applications, including emergency disaster relief when the conventional infrastructure based communication facilities are destroyed due to war, hurricanes, or earthquakes. They are also used for applications such as audio-video conferencing and sharing text/images dynamically using their mobile devices. These applications lend themselves well to multicast operation.

However, the ad-hoc multicast routing is comparatively new research domain with respect to unicast routing. Up till now, the propositions in this subject are scarce compared to unicast routing, and standardization process is on-going. Moreover, performance studies are limited and have not been reported extensively. Accordingly, multicasting in ad-hoc networks is a promising research area that requires considerable further study.

There are several on-demand multicast protocols proposed for MANET, namely, Multicast Ad-hoc On-Demand Vector (MAODV), On-Demand Multicast Routing Protocol (ODMRP) and Adaptive Demand-Driven Multicast Routing (ADMR) Protocol. To our knowledge, there has not been any reported study to these protocols extensively. Thus, performances characteristics of each of these protocols are considered necessary to be evaluated and analyzed in proper context so that the usefulness and the enhancement can be identified.

1.3 SCOPE

This thesis focuses on the on-demand multicast protocols as previous studies (Lee, Su, Hsu, Gerla and Bagrodia., 2000) have shown that in general, protocols based on on-demand strategy are better suited for MANET because they generate less control overhead. Therefore, we particularly concentrate on MAODV, ADMR and ODMRP since they are the state of the art multicast routing protocols in MANET.

More precisely, we are concerned upon two key issues of the structure of multicast protocols, which are tree-based and mesh-based. The three protocols also represent tree-based (MAODV and ADMR) and mesh-based protocols (ODMRP). Hence, the merits of tree- and mesh-based protocols can be characterized.

1.4 OBJECTIVE

In general, the objective of this thesis is to observe and evaluate state of the art of multicast routing protocols for mobile ad-hoc networks based on their performance.

The detail objectives are listed as follows:

1. To study and explore state of the art multicast routing protocols in MANET.
2. To perform a comprehensive performance evaluation and comparison of the multicast protocols based on a specific set of performance metrics under various network scenarios.
3. Insight into possible improvement that can be made in the area of on-demand multicast routing for MANET.
4. To enhance NS-2 functionality as a simulation environment to support the ad-hoc network that could be used for further study within the area of multicasting in ad-hoc networks.

1.5 METHODOLOGY

This thesis work is based on simulation study which is based on NS-2 Simulation. The simulation is done to see how concrete protocols perform. Therefore, as yardstick, various performance metrics are discussed. By doing the simulations, how much improvement can be achieved by the protocols can be seen and what kind of scenario can get benefit from the protocols will be analyzed. Moreover, in order to achieve the objective of this research, the following flow diagram shows the steps that have been employed:

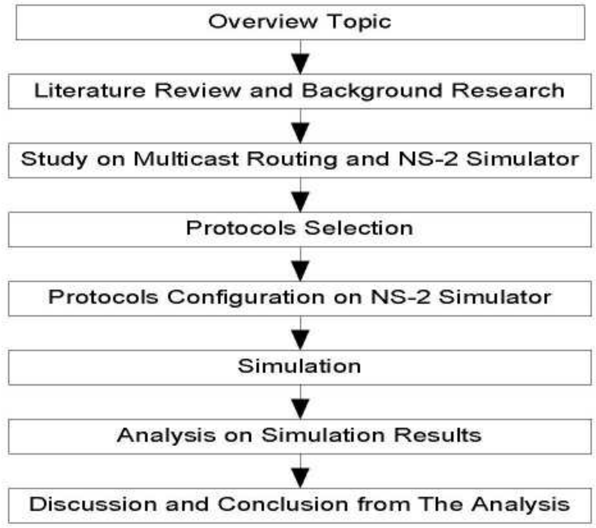

Figure 1.1 Flow Diagram of Thesis Methodology

1.6 THESIS OUTLINE

The thesis consists of six chapters:

- Chapter 1: Gives the introduction to this thesis. The introduction consists of background, problems, scope, objectives and research methodology.
- Chapter 2: Generally, presents literature review on multicasting and MANET, then it goes to investigate some specific multicast protocols.
- Chapter 3: Describes the operation of MANET multicast protocols under investigations. The qualitative comparisons of the protocols are also presented.
- Chapter 4: Discusses the simulation environment and the evaluation metrics which is used to see the performance of the protocols.
- Chapter 5: This chapter provides a discussion on the simulation results and present possibility of protocols enhancement.
- Chapter 6: The thesis ends with conclusion and suggestion for the future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW ON MULTICAST

Multicast is used as support to group communication, where several destinations can receive a data packet by a single transmission. This does not involve all hosts connected to a network, but only a defined subset of these hosts, that is the multicast group.

Multicast is introduced for group communication to reduce communication cost. Since data can be transmitted to all receivers using single transmission, it provides efficient saving in bandwidth and network resources (Nikaein, 2000). On the other hand, in traditional unicast technique, the source transmits the same information more than once to several destinations. Figure 2.1 illustrates this interest in multicast. When using the unicast technique, we notice the redundancy in data packet transmission as shown in Figure 2.1(a), Over the links (Source-A), (A-B), and (A-C). when applying the multicast technique in Figure 2.1(b), no redundancy takes place during the transmission.

However, some technological constrains are required to apply this multicast technique (Rougier, 1999). First, a multicast addressing should be associated with each multicast communication and the nodes wishing to participate at the multicast session should join this address. As well, a multiplication capacity should exist at the networks nodes, where they should have the capacity for duplicating the received information. The interest of this multiplication is to make economic use of bandwidth in the network.

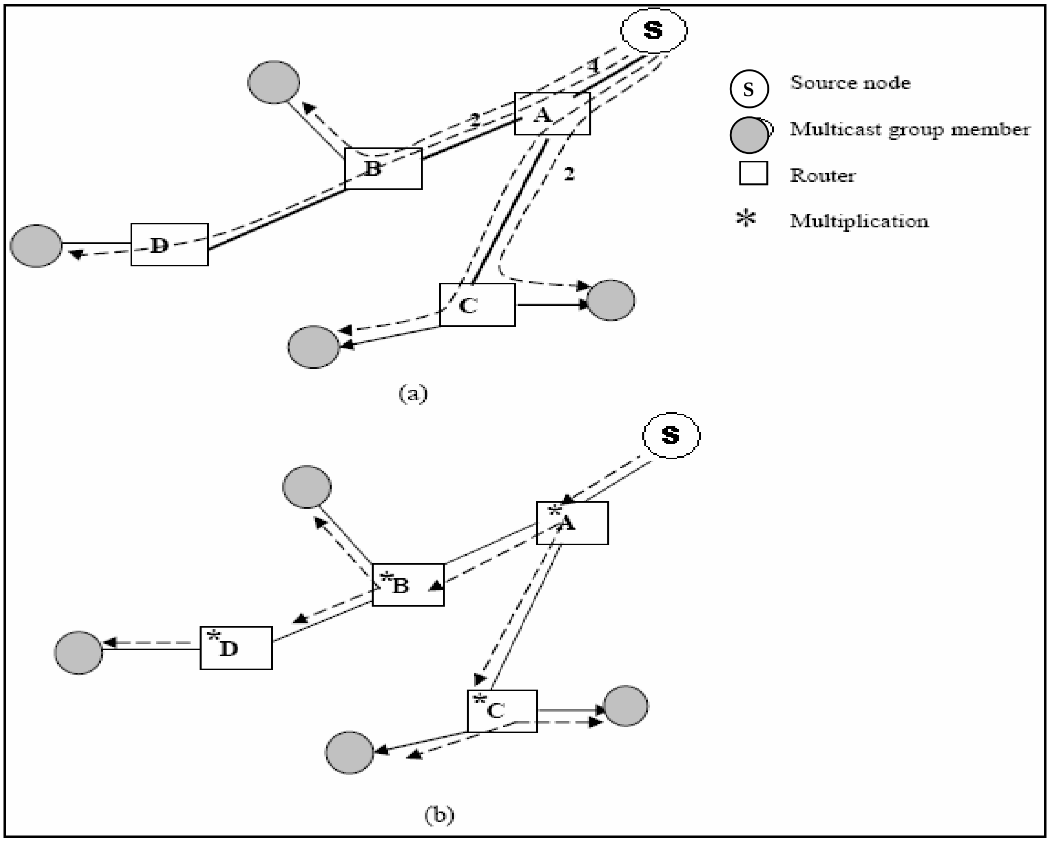

Figure 2.1 (a) Unicast Diffusion versus (b) Multicast Diffusion

Multicast application is mainly useful for multipoint or group applications, including software distribution, replicated database update, command and control system, and distributed interactive simulation (Rougier, 1999). Furthermore, it is of great interest for video and internet conferences (Lee and Kim, 2000). As well as distributed applications including: distributed games and collaborative work such as distributed simulation and shared text processing (Nikaein, 2000).

2.2 CONVENTIONAL MULTICAST PROTOCOLS

Multicast routing protocols for the conventional wired networks address the issue of routing structure which connects source(s), destinations and forward data packets using this structure. Discovering all receivers behind a multicast address is accomplished during the structure construction phase when group receivers join the structure. Through this way, these protocols focus on the problem of the minimum cost structure for packet forwarding. Here, the cost could be distance, delay, and so on. Tree multicast structure is a well established concept in wired environment. There are two popular network multicast tree schemes, namely, *the shortest path multicast tree* and *shared tree (*Wang, Bin and Hou., 2000). They are differentiated in terms of how multicast tree are constructed.

The shortest path multicast tree guarantees the shortest path to each destination through the links of multicast tree. Kunz (2002) mentioned this scheme as *per-source tree* scheme since each source node builds a separate tree rooted at itself. Nodes broadcast the packet from the source to all destinations along this tree using “Reverse Path Forwarding” or RPF. An arbitrary network node will accept the packet broadcast by source node as long as the packet is received along the shortest path from forwarder/router to the source node. Thus, only those packets are forwarded that arrive on the reverse shortest path from the router to sender (Kunz, 2002). This provision is required in order to avoid endless looping (Gerla, Chiang and Zhang, 1998). The examples protocols that employ of *per-source tree* are DVMRP (Pusateri, 2000) and PIM Dense Mode (Deering, Estrin, Farinacci, Jacobson, Liu and Wei, 1996). The per-source tree comes with many attractive properties for wired environment. For example, the shortest path tree rooted at each source (sink tree) generally comes for free since it is embedded in the routing tables of the most common routing algorithms such as *Distance Vector* and *Link State*. Additionally, the multicast tree of the source node distributes the traffic evenly in the network (assuming that the source and receivers are evenly distributed), it requires minimal initialization and maintenance, and it does not rely on a central control point (e.g., Rendezvous Point).

In mobile networks, the *per-source tree* approach for multicasting presents a problem. Suppose a source moves faster than the routing tables track it. In this case, some of the nodes will have obsolete routing tables which point in the "wrong direction". Following the "Reserve Path Forwarding" principle, multicast packets are dropped at such nodes and may never reach some of the receivers (Gerla et al., 1998). However, the periodical full broadcast in implementations like DVMRP introduces costly control overhead on the low bandwidth wireless channel and is not suitable for sparse distributed membership and scaling the network size (Kunz, 2002).

Another popular wired network multicast scheme is shared tree. In this scheme, one node for each group is selected as the core or termed *rendezvous point* (RP). So, each multicast group constructs only a single tree rooted at RP (instead of many per-source trees) to span all the group members. The intermediate routers in the tree are responsible for forwarding the multicast data to members. In this manner, all receivers join the multicast group by explicitly sending a *join* message towards the RP. Senders send data to the RP, and the RP uses a single unidirectional shared tree to distribute the data to the receivers. The Core Based Tree (CBT) (Ballardie et al., 1993) and PIM Sparse Mode (Deering et al., 1996) are representatives of shared tree.

Basically, a very fast source will send its packet to RP in unicast mode. Packets are correctly delivered to the RP on shortest paths, irrespective of the speed of the source. The RP will then multicast the packet on the shared tree to the intended destinations. This works as long as the shared tree is stable and the RP itself is not fast moving. If all the nodes are moving fast (relative to the routing table updates), the shared tree solution fails.

Kunz (2002) lists some drawbacks of the shared tree approach with respect to the per-source scheme. First, paths are non optimal and traffic is concentrated on the