A NEW ROUTING METRIC FOR DYMO PROTOCOL ON MOBILE AD HOC NETWORK

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ABSTRACT

Mobile ad hoc networks (MANETs) are consists of mobile devices connected wirelessly. MANETs communicate without any fixed infrastructure or any centralized domain. All the nodes are free to move randomly within the network and share information dynamically. Routing protocol in MANET show how the mobile nodes messages are forwarded in a multi-hop fashion. The wireless connectivity and node mobility in MANET networks contributes in rapid topological changes, which brings the need for a channel aware routing protocol. Hence, the need for efficient routing protocols to allow the nodes to communicate. In such a communication scheme a routing protocol play an important role in the network performances. Achieving high user data rates over multi-hop wireless paths is considered the ultimate goal for MANET. To overcome this problem, several important modifications to the routing protocol algorithms are then considered to operate better in networks. This research work proposed a SNR-based routing metric for Dynamic Mobile Ad hoc Network onDemand (DYMO) routing protocol. This paper starts by investigate and compare the performance among reactive routing protocols in MANET. Secondly, the DYMO protocol choose routes based on SNR metric are modeled as proposed the new routing metric. Simulations scenarios are used for the work of the research by develop the new routing metrics in DYMO protocol module in OMNET++. The results show that SNR-DYMO improves the performance of the MANET in terms of throughput and packet delivery ratio throughout all simulation scenarios.

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ABSTRAK

Rangkaian Mudah Alih Ad Hoc (MANET) adalah terdiri daripada peranti mudah alih disambungkan tanpa wayar. MANET berkomunikasi tanpa sebarang infrastruktur tetap atau domain berpusat. Semua nod bebas untuk bergerak secara rawak dalam rangkaian dan berkongsi maklumat secara dinamik. Protokol penghalaan MANET menunjukkan bagaimana maklumat yang dibawa oleh nod mudah alih dikemukakan dengan cara multi-hop. Sambungan tanpa wayar dan pergerakan nod dalam MANET menyumbang ke arah perubahan topologi yang pesat, yang membawa keperluan untuk saluran sedar protokol penghalaan. Oleh itu, protokol penghalaan yang berkesan adalah penting untuk nod berkomunikasi. Dalam sebarang bentuk komunikasi, protokol penghalaan memainkan peranan penting dalam persembahan rangkaian. Usaha meningkatkan kadar data pengguna ke atas laluan multi-hop tanpa wayar dianggap keutamaan MANET. Untuk menjayakan matlamat ini, beberapa pengubahsuaian penting kepada algoritma protokol penghalaan perlu dilaksanakan bagi membolehkan ia beroperasi dengan lebih baik. Kajian ini mencadangkan SNR berasaskan parameter laluan kepada protokol penghalaan Dynamic Mobile Ad hoc Network onDemand (DYMO). Kajian ini bermula dengan membandingkan prestasi parameter bagi protokol penghalaan jenis reaktif di dalam MANET. Seterusnya, mengubah suai protokol DYMO yang memilih laluan berdasarkan parameter SNR seperti yang dicadangkan sebagai parameter protokol penghalaan yang baru. Senario simulasi telah digunakan dalam kajian ini dengan membangunkan parameter baru untuk protokol DYMO menggunakan OMNET++ modul. Hasil dapatan kajian ini telah menunujukkan bahawa SNR-DYMO boleh meningkatkan prestasi MANET seperti *throughput* dan nisbah penghantaran paket melalui simulasi.

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LIST OF SYMBOLS AND ABBREVIATIONS

AODV	-	Ad hoc On-demand Distance Vector
ARP	-	Address Resolution Protocol
CPU	-	Central Processing Unit
DSDV	-	Distance Sequenced Distance Vector
DSR	-	Dynamic Source Routing
DYMO	-	Dynamic Mobile Ad hoc Network Ondemand
ETX	-	Expected Transmission Count
GNED	-	Graphical Network Description
GUI	-	Graphical User Interface
IM-AODV	-	Improve of Ad hoc On-demand Distance Vector
IP	-	Internet Protocol
LAN	-	Local Area Network
LANMAR	-	Landmark Ad-hoc Routing Protocol
MAC	-	Media Access Control
MANET	-	Mobile Ad hoc Network
Mgmt	-	Management
NCI	-	Node Connectivity Index
OLSR	-	Optimized Link state Routing
OSI	-	Open System Interconnection
P_f	-	Forward Delivery Ratio

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P_r	-	Reverse Delivery Ratio
PDR	-	Packet Delivery Ratio
PktPair	-	Per-hop Packet Pair
QoS	-	Quality of Service
QRY	-	Query
RERR	-	Route Error
RMS	-	Root Mean Square
RREP	-	Route Reply
RREQ	-	Route Request
RTS	-	Request To Send
RTT	-	Round Trip Time
SNR	-	Signal-to-Noise-Ratio
TCP	-	Transmission Control Protocol
TORA	-	Temporally-Ordered Routing Algorithm
WCETT	-	Weighted Cumulative Expected Transmission Time
WMNs	-	Wireless Mesh Networks
WRP	-	Wireless Routing Protocol
ZRP	-	Zone Routing Protocol

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CHAPTER 1

INTRODUCTION

1.1 Background

Recent advances in portable computing and wireless technologies create an exciting possibility for the future of wireless mobile networking. Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration [1]. MANETs are self-organized and fully distributed networks that rely on the collaboration of participating devices to route data from source to destination. The MANET paradigm is expected to enable ubiquitous mobile communication and thus the proliferation of pervasive applications [2]. As opposed to infrastructure wireless networks, where by each user directly communicates with an access point or base station, a node within MANET does not rely on a fixed infrastructure for its operation. Hence, MANET is suited for use in situations where a fixed infrastructure is not available, not trusted, too expensive, or unreliable [3].

Many routing protocols are developed for MANETs over the past few years. Routing protocol is a standard that controls selection of the route for routing packets between nodes in MANET. J.Hoebeke et al [2] have stated that in order to develop the efficient routing protocols for MANETs remains a challenging task. It is well known that every protocol is capable of outperforming the others depending on the

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network context under which it is evaluated. Each protocol performs optimally under specific network conditions due to their limited behavioral adaptively, which both varies in time and place. Performance of MANET depends on the routing protocol and battery consumption by the nodes. There are various Quality of Service (QoS) parameters which affect its performance [5]. G.Vijaya Kumar et. al.[7] have concluded in their research that ~~the~~ depending on the amount of network traffic and number of flows, a suitable routing protocol~~s~~ could be implemented. When congestion occurred in the network due to heavy traffic, in general case, a reactive protocol is preferable. Sometimes network size might be a major considerable point. For example, AODV, DYMO, DSR, OLSR are some of the protocols suitable for relatively small MANET, while protocols like TORA, LANMAR, ZRP are more suited for larger networks.

1.2 Problem statement

A mobile ad hoc network, MANET is a collection of two or more devices with wireless communications and networking capabilities that communicate with each other without the aid of any centralized administrators. The network topology is dynamic, because the connectivity among the nodes may vary with time due to node mobility, departures and new arrivals. Hence, the need for efficient routing protocols to allow the nodes to communicate.

MANET also is an emerging technology that offers a cost-effective and scalable method to connect wireless devices. Although MANET is considered a convincing candidate for better wireless services, research to enhance its functionality is still in its infancy. Achieving high user data rates over multi-hop wireless paths is considered the ultimate goal for MANET. Towards this goal many enhancement can be done by using advance routing layer solutions. Several important modifications to the routing algorithms are then considered to operate better in networks. In this research work, due to the nature of MANET, we study the use of Signal-to-Noise Ratio (SNR) as link-quality metric to provide an alternative routing metric rather than the classical hop-count. We believe that by modifying the existing routing protocols to use the SNR as routing criteria, routing protocols will

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perform well and achieve better route decision in MANET. SNR as link-quality metric is better due to low overhead needed in calculating the SNR value of the wireless link as compared to other link-quality metrics. In [41] the implementation and evaluated the performance of the modified SNR on DSDV protocol against the traditional hop count metric, it results show that, the SNR-based metric gets higher throughput and packet delivery ratio than the traditional hop count. Also the new metric achieves a smaller end-to-end delay than the traditional hop count metric.

Most of the existing MANET routing protocols (e.g. Ad-hoc On-demand Distance Vector (AODV), Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR)) simply use minimum hop-count as metric for identifying the best packet routes [42]. However, in MANET paths with minimum hop-count can have poor performance because they may tend to include wireless links between distant nodes. The dynamicity of MANET topology is due to nodes mobility. The connectivity failed, if a node inadvertently fails and secondly when the spatial density of the nodes is too low. Connectivity is one of the most fundamental aspects of MANET. Network connectivity of MANET is a complex problem due to the uncertainty of the network topology [51]. These wireless links can be slow or lossy, leading to poor network throughput [21, 26, and 27]. Therefore, a routing protocol can select better routes by explicitly taking into account the quality of the wireless links rather than the number of hops between source and destination nodes [43].

Various link-quality metrics have been proposed for measuring the quality of the wireless links. Some of these metrics are based on measuring the round trip delay between neighbouring nodes (e.g. RTT) whereas; some of these metrics are based on measuring the average loss rate of packets between pair of neighbouring nodes (e.g. ETX) [23, 24, 43]. Although these metrics evaluate the quality of the wireless link properly, but they send periodic network probes between neighbouring nodes to help in measuring the quality of the link. These additional probes add undesirable overheads which in turn reduce the overall network throughput and accordingly lead to network performance degradation.

Consequently, the need for link-quality metric which reduce the overheads of measuring the quality of the link and improve the routing capability of the existing routing protocols is required to provide high-throughput and to achieve better packet route decision in MANET.

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1.3 Statement of objectives

The aim of the research is to improve the performance of Dynamic Mobile Ad hoc Network Ondemand (DYMO) routing protocol. Hence the objectives can be summarized as follows:

i). To investigate the following routing protocol for MANET: DSR, AODV and DYMO;

ii). To propose and model Signal-to-Noise Ratio (SNR) as a new routing metric;

iii). To evaluate the performances of the SNR-DYMO using OMNET++.

1.4 Project scope

In our research work, we select the existing reactive routing protocol to review as Ad hoc On-Demand Distance Vector (AODV), Dynamic Mobile Ad hoc Network Ondemand (DYMO) and Dynamic Source Routing (DSR) protocol as the examples of routing protocol used in MANET. We select DYMO protocol to evaluate the network performances after applying the Signal-to-Noise Ratio (SNR) as routing metric into DYMO protocol.

We use OMNET++ simulator for simulation purposes. In this simulator we used the following limitation of parameter for the configure the performance of the investigate existing reactive routing protocol;

i). Size of layout : 5000m x 4000m

ii). The number of node : 40, 80, 120, 160 and 200.

iii). Nodes mobility speed: 2mps, 4mps, 6mps, 8mps and 10mps.

Our research work also focuses on modifying the *route discovery* process of DYMO protocol to select a route based on the SNR feedback from the physical layer. Each node monitors the quality of the link's statistics by measuring the SNR of all packets received from immediate neighbours. The DYMO routing module provided by OMNET++ simulator has been adapted to use SNR metric instead of hop-count for packet route selection.

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1.5 Proposed Solution

In this research work, we propose the use of Signal-to-Noise Ratio (SNR) as routing metric to measure the quality of the wireless link in MANETs. We will then evaluate the routing capability of Dynamic Mobile Ad hoc Network Ondemand (DYMO) protocol after applying SNR as routing metric. The evaluations are done by comparing the overall network performance of Dynamic Mobile Ad hoc Network Ondemand (DYMO) protocol before and after applying SNR as routing metric.

1.6 Organization of the Study

The remainder of this thesis is organized as follows:

Chapter 2 presents an overview about MANET and their characteristics, architectures, some challenges, and reviews the existing protocol for routing in MANET. The chapter also presents the related work and discusses the DYMO protocol in details. The chapter presents the routing operations of DYMO protocol and discusses the major strengths and weaknesses of DYMO protocol.

Chapter 3 presents the research methodology and discusses how Signal-to-Noise Ratio (SNR) can be applied to DYMO protocol to provide better routing capabilities. The Chapter presents the modification of DYMO protocol to accept the SNR as routing criteria instead of the classical hop-count metric.

Chapter 4 discusses the simulation environment setup and presents the configuration parameters of the routing protocols used in our simulation study.

Chapter 5 presents the results obtained from T-Test Data analysis tool for the purpose of data verification and also analyzes and discusses the simulation results.

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Chapter 6 presents the conclusion and summarizes the major contributions and findings of this master thesis followed by some future work.

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CHAPTER 2

LITERATURE REVIEW

This chapter presents the fundamentals of mobile ad hoc networking and the challenges faced in MANET routing protocol. In this chapter also we discuss the major families of the routing protocols used in MANET. We present one protocol from each family to show the routing behavior of the family. Afterwards some routing metrics in MANET are reviewed as hop count, Round Trip Time (RTT), Expected Transmission Count (ETX) and Node Connectivity Index (NCI). Additionally, we present some of the performance metrics definitions.

2.1 Introduction

The use of wireless technology has become a ubiquitous method to access the Internet or connect to the local network whether in a corporate, educational, or private setting. Nowadays, there is an increasing need for interconnection of several devices, in order to satisfy particular needs. MANETs are networks formed in cases were networking infrastructure is either unavailable or totally absent. Using wireless interfaces, hosts may communicate with each other directly if each one falls within the communication radius of the other.

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2.1 MANETs

MANET is a collection of wireless nodes that can dynamically be set up anywhere and anytime without using any pre-existing network infrastructure. It is an autonomous system in which mobile hosts connected by wireless links are free to move randomly and often act as routers at the same time. It’s also self-configuring infrastructure less network of mobile devices connected by wireless links. Ad hoc is Latin and means "for this purpose"[10]. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet.

MANET shared wireless medium communicate with each other without the presence of a predefined infrastructure or a central authority. The member nodes are themselves responsible for the creation, operation and maintenance of the network. The nodes which are not in wireless vicinity, communicate with each other hop by hop following a set of rules (routing protocol) for the hopping sequence to be followed. MANETs require these routing protocols to cope well with dynamism of topology, and nodes should cooperate trustfully in order to establish genuine routes [12]. The absence of a central controlling node makes it possible the network will be still operational even though one node collapses. In an Ad-hoc network two nodes, which wish to communicate, might not be in transmission range of each other in such cases a MANET uses multiple hops to communicate. Ad-hoc networks are also capable of handling topology changes caused due to mobility or if a node decides to stop participating in the network. But inherently nodes participating in an Ad-hoc network are willing to forward data packets belonging to other node as opposed to infrastructure networks [9]. Thus each node participating in ad-hoc network acts both as host and routing node as well. Figure 2.1 shows a simple four node ad-hoc network.

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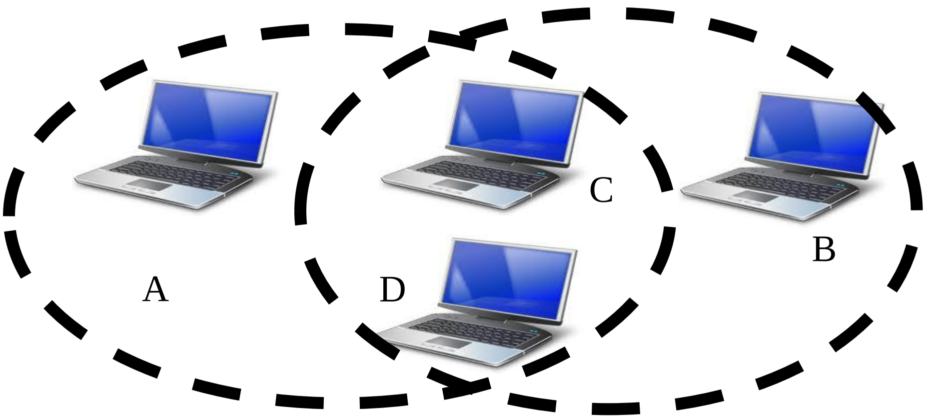

Figure 2.1: Showing nodes where node A and B are not in direct transmission range of each other and therefore uses C as an intermediate hops for communication.

2.2 Routing Protocol On MANET

Routing is the process of exchanging packets of information between nodes in network. The main purpose of a routing protocol is to supply routing nodes with information on which nodes that can be used to reach which destinations. Packets are sent via the communication channels from source to the destination. That connection between source and destination is called route or path. The route is composed of at least two nodes; the source which is the node that initiates the communication and the destination which is the target to receive the communication. Sometimes the source and the destination are not in close proximity to each other to allow direct communication. In that case they bring into play intermediate nodes so that they can help in relaying packets and then a route will be composed of more than two nodes. The methods that nodes use to connect to each other and to forward packets for each other are handled by routing protocols.

As shown in figure 2.2, routing protocols for Ad hoc network can be classified into three main families. Under each family, there are more than one protocol have been proposed. The following sections describe briefly these families and overview one protocol from each family as an example to show the behavior of the family.

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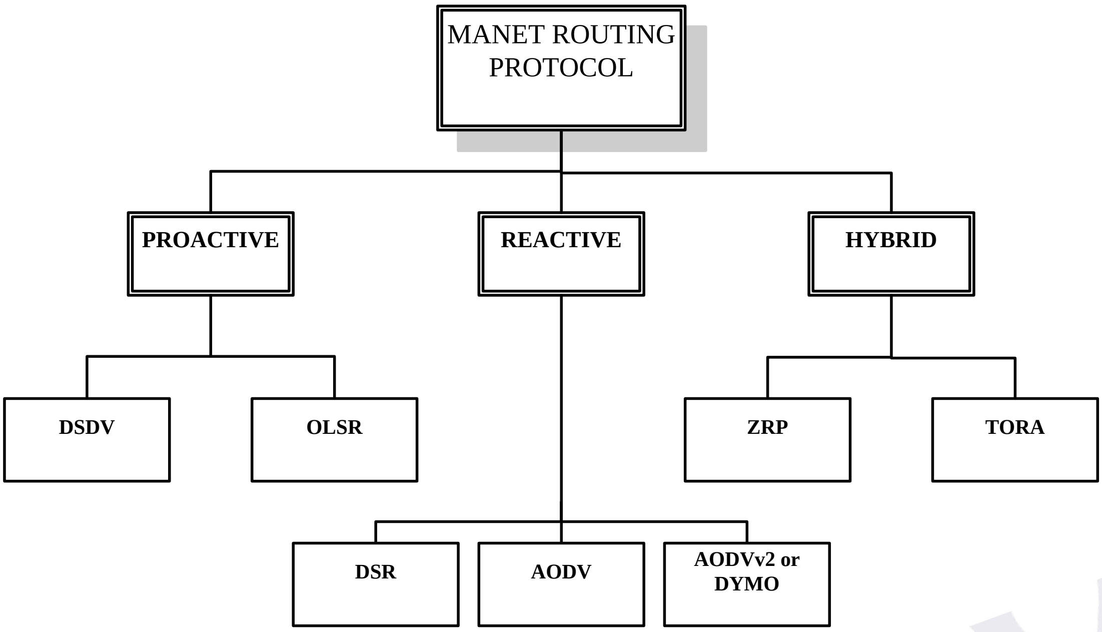

Figure 2.2: Classification of Routing Protocols in MANET

Numerous routing protocols for MANET have been proposed and well-studied. These include Ad hoc On-Demand Distance Vector (AODV) [6,7,16,18,21],Dynamic Mobile Ad hoc Network On demand (DYMO)[4,6 ,11,13,14,15,16,17,18] and Optimized Link State Routing (OLSR) [4,7,18] .Most evaluations of these routing protocols are based on stationary nodes and simulations. Performances of these protocols are tested based on different link metrics such as HOP, Round Trip Time (RTT), and Expected Transmission Count (ETX) [19]. Since the per-hop RTT metric performs poorly due to self-interference [20], DSR is applied with three link quality metrics: HOP, ETX, and WCETT. In [21], an improved performance metric based protocol named by IM-AODV has proposed which will able to select more reliable path. Proposed performance metric as integrated metrics (combination of ETX, RTT and Hop Count) is implemented in IM-AODV. The main goal of IM-AODV is to ensure a reliable path. Simulation result shows that IM-AODV performs better than traditional AODV.

2.2.1 Proactive routing protocols

A proactive routing protocol knows about all announced paths to other nodes in the network, even if this node or router has not sent any messages to that destination. This behavior will avail the need to request for a route to a destination when a packet is to be delivered. One of the downsides of this behavior will be that traffic will be sent to keep route tables updated. This is not a problem when the network is stable or wired, because the overhead of routing messages will not be a factor in compared to bandwidth consumption. If nodes in the network start moving around and are connected through a wireless media; and these nodes are involved in the process of routing messages; the overhead could limit the bandwidth that applications could use. The nodes exchange topology information with each other; they can have route information any time when they needed. Some of the existing proactive routing protocols are DSDV [41], OLSR [4,7,18] and Wireless Routing Protocol (WRP)

2.2.2 Hybrid Ad hoc Routing Protocols

This section introduces a hybrid model that combines reactive and proactive routing protocols but also a location assisted routing protocol. Both of the proactive and reactive routing methods have some advantages and shortcomings. In hybrid routing a well combination of proactive and reactive routing methods are used which are better than the both used in isolation. It includes the advantages of both protocols. As an example facilitate the reactive routing protocol such as AODV with some proactive features by refreshing routes of active destinations which would definitely reduce the delay and overhead so refresh interval can improve the performance of the network and node. So these types of protocols can incorporate the facility of other protocols without compromising with its own advantages. Examples of hybrid protocols are Zone Routing Protocol (ZRP)[6] and Temporally Ordered Routing Algorithm (TORA)

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2.2.3 Reactive routing protocols

A characteristic trait of reactive routing protocols is that they only search for a route to a destination when they need to send data to that host. When a reactive protocol tries to find a destination it will, usually, broadcast a request for a path to that host, additional information about how to reach other hosts could be considered to be beneficial for future communications and may also be added to the request by intermediate nodes. Some of the main goals of reactive routing protocols are to minimize the amount of overhead needed before data is sent to the destination and to handle changes in network topology. Some well-known reactive routing protocols are AODV] [6,7,16,18,21], DSR[41,57] and DYMO[4,6 ,11,13,14,15,16,17,18].

2.3.2.1 Ad-hoc On-demand Distance Vector routing (AODV)

AODV is based on distance vector routing [6] where the routing table contains, among other entries, the next hop to reach the destination, with one entry for each destination [7]. To know when received routing information, about a destination that already exists in the local routing 5 table, is better AODV uses sequence numbers, these sequence numbers is maintained at each destination and are transmitted when a node answers a request that are addressed to itself. The sequence number is also used to prevent that routing loops arise in the network. As AODV is supposed to be used in a mobile wireless environment it uses timers to know when a route should be deposed of, from the local routing table. If this behaviour did not exist a node may try to send data to a destination that is not reachable through the ordained next hop.
A request for a new path to a destination is done through a route request, RREQ, and the reach of the RREQ will be determined by the TTL field in the IP header [21]. AODV keeps track of which neighboring nodes use which next hops and in the case that the next hop becomes unavailable it will send a route error (RERR) to those nodes and they will in return forward the RERR to their concerned parties.

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i) Route Discovery

Node S wishes to communicate with a node T initiates RREQ message including the last known sequence number for T and a unique RREQ id that each node maintains and increments upon the sending of an RREQ. The message is flooded throughout the network in a controlled manner. Each node forwarding the RREQ creates a reverse route for itself back to S using the address of the previous hop as the next hop entry for the node originating the RREQ. When the RREQ reaches a node with a route to T a RREP, containing the number of hops to T and the sequence number for that route, is sent back along the reverse path. An intermediate node must only reply if it has a fresh route, i.e., the sequence number for T is greater than or equal to the destination sequence number of the RREQ. Since replies are sent on the reverse path. Route discovery is illustrated in figure 2.3 [59].

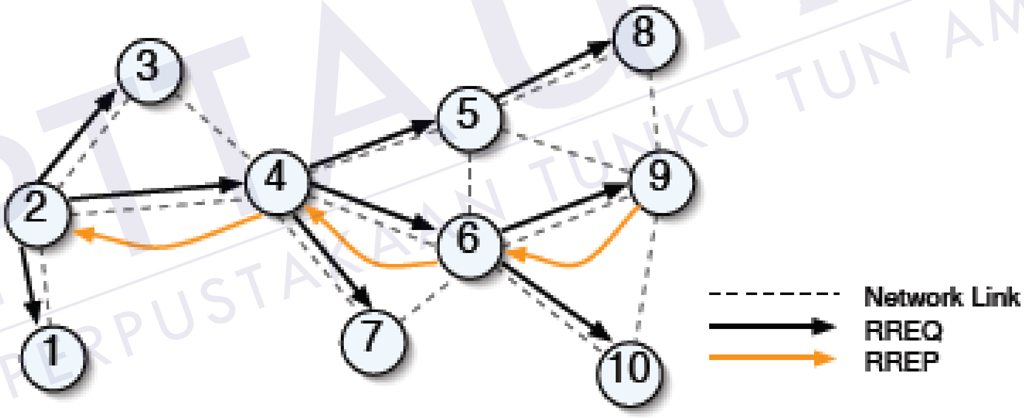

Figure 2.3: Route discovery in AODV [59]

If an intermediate node has a route to a requested destination and sends back an RREP, it must discard the RREQ. Furthermore, it may send a gratuitous RREP to the destination node containing address and sequence number for the node originating the RREQ. Gratuitous RREPs are sent to alleviate any route discovery initiated by the destination node.

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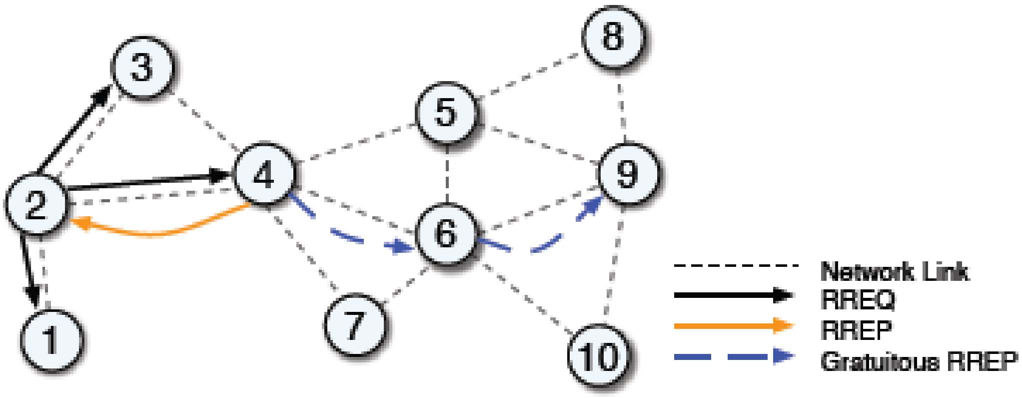

Figure 2.4: Generation of an RREP by an intermediate node [59].

ii) Route Maintenance

It is the process of responding to changes in topology. To maintain paths, nodes continuously try to detect link failures. Nodes listen to RREQ and RREP messages to do this. Furthermore, each node promises to send a message every n seconds. If no RREQ or RREP is sent during that period, a Hello message is sent to indicate that the node is still present. Alternately, a link layer mechanism can be used to detect link failures. When a node detects a link break or it receives a data packet it does not have a route for, it creates and sends a Route Error (RERR) packet to inform other nodes about the error. The RERR contains a list of the unreachable destinations. If a link break occurs, the node adds the unreachable neighbour to the list. If a node receives a packet it does not have a route for, the node adds the unreachable destination to the list. In both cases, all entries in the routing table that make use of the route through the unreachable destination are added to the list. The list is pruned, as destinations with empty precursor lists, i.e., destinations that no neighbours currently make use of, are removed. The RERR message is either unicasted (in case of a single recipient) or broadcasted to all neighbours having a route to the destinations in the generated list. This specific set of neighbours is obtained from the precursor lists of the routing table entries for the included destinations in the RERR list. When a node receives an RERR, it compares the destinations found in the RERR with the local routing table and any entries that have the transmitter of the RERR as the next hop, remains in the list of unreachable nodes. The RERR is then either broadcasted or unicasted as

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described above. The intention is to inform all nodes using a link when a failure occurs. For example, in figure 2.5, a link between node 6 and node 9 has broken and node 6 receives a data packet for node 9. Node 6 generates a RERR message, which is propagated backwards toward node 2 [59].

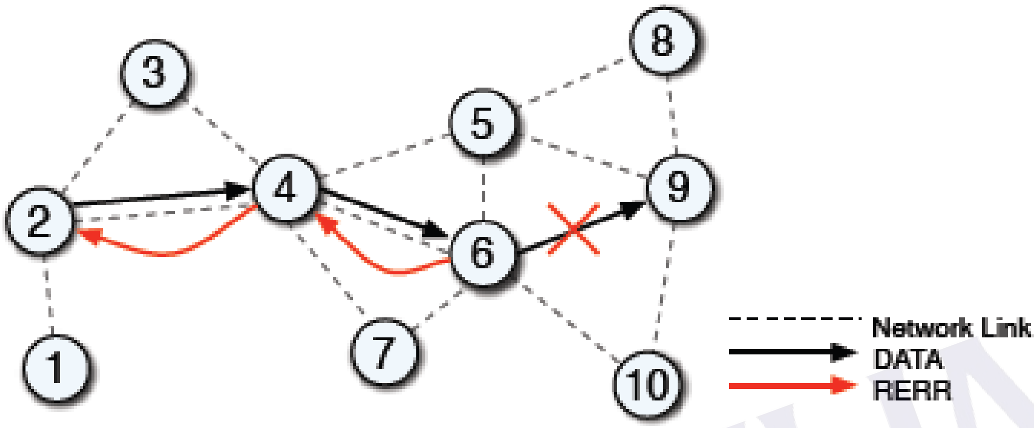

Figure 2.5: Generation of RERR messages. [59].

To find a new route, the source node can initiate a route discovery for the unreachable destination, or the node upstream of the break may locally try to repair the route, in either case by sending an RREQ with the sequence number for the destination increased by one.

2.2.3.2 Dynamic Source Routing (DSR)

A routing entry in DSR contains, in contrast to AODV, the full path to the destination with all intermediate hops. The local routing table can contain multiple entries to one destination [41]. To discover a route to an unknown destination DSR floods the network with RREQ packets. When a node receives a RREQ it will check in its local routing table if it knows a route to the destination, or if it is the destination, and in such cases it will send a route reply, RREP, to the originator of the RREQ by traversing the source route backwards. All other nodes will record the given information and then retransmit the RREQ, after adding the local host entry. In that way the full path to the originator of the RREQ will be known to all hosts that

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receive the RREQ. If a link is broken the source of the message is notified with a RERR and the source will remove the faulty route from its local routing table and send a RREQ if it does not know any other way to reach the destination [41][57].

i) Route Discovery

Route discovery mechanism is illustrated in figure 2.6. Node 2 has a data packet to send to node 9 and floods a RREQ in the network. The RREQ packet contains a unique request id generated by the source node and a record listing the addresses of all intermediate nodes. Each node receiving the RREQ rebroadcasts the packet, if the node is not the target, it has not forwarded the packet previously, and it does not find its own address already listed in the route record. The request id of the RREQ is used to check for already forwarded packets, i.e., duplicate RREQs. Finally, the node appends its address to the route record of the packet [59].

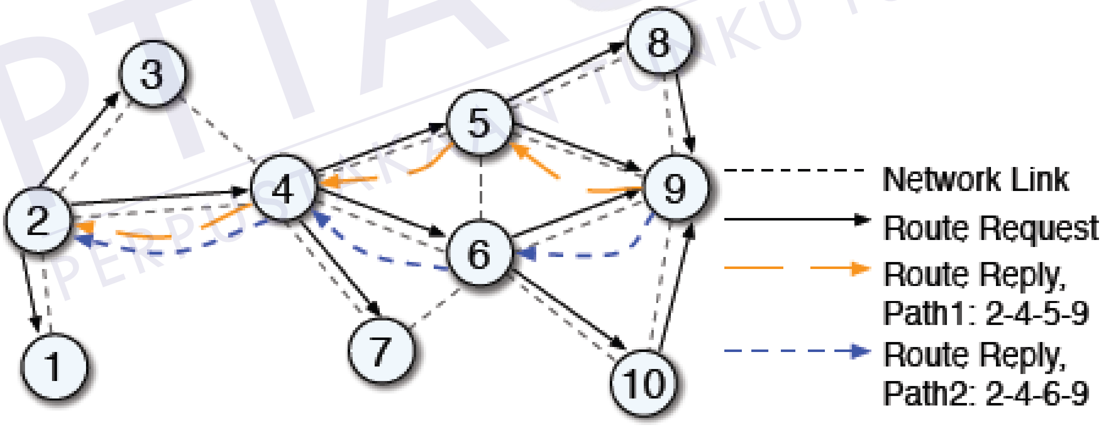

Figure 2.6: The route discovery process for DSR. [59].

The RREQ arrives at node 9 via different routes and the node then returns a Route Reply (RREP) to node 2, the initiator of the route discovery, containing the recorded route. When node 2 receives the RREP sent by node 9, it saves the listed route in its route cache for use for subsequent sending. The RREP can be returned various ways shown in above figure 2.6 [59].

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ii) Route Maintenance

Each node transmitting a packet is responsible for ensuring that the next hop neighbor receives the packet. This can be performed in three ways: It can either per-hop acknowledgements, passive acknowledgements, or finally a flag set in a DSR control packet requesting explicit next hop acknowledgement. Upon detection of a link break when forwarding a packet, a RRER error packet is sent to the node originating the packet, stating the link that is currently broken. For example, in figure, node 9 has moved outside the transmission range of node 6 and it is unable to deliver the data packet to node 9 [59].

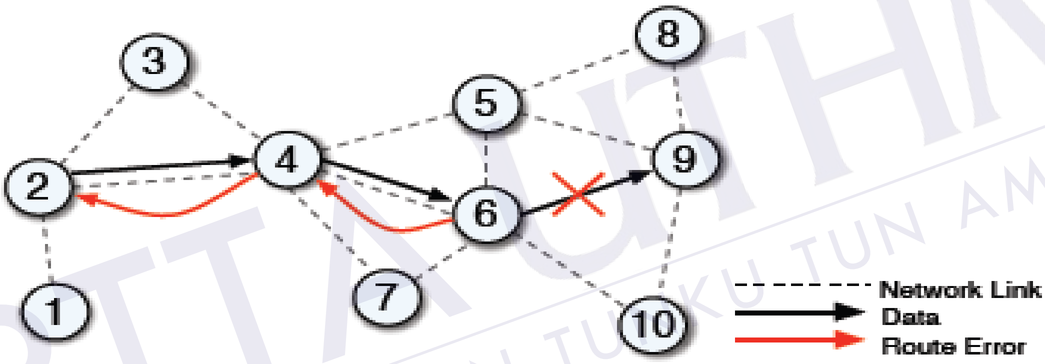

Figure 2.7: Route maintenance. [59].

Node 6 then returns RERR to node 4 that in return propagates it to node 2, the original sender, which removes the route from its route cache. It can then use another cached route (for example, the path 2-4-5-9 learned from the previous route discovery), or perform a new route discovery for node 9.

2.2.3.3 Dynamic Mobile Ad hoc Network Ondemand (DYMO)

Communication devices have become one of the most important instruments to stay in touch with each other. Over the years, engineers have been working to enhance the network protocols used by these devices for better communication. Dynamic Mobile

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Ad hoc Network Ondemand (DYMO) routing is one such protocol that is intended for the use by mobile nodes in wireless multihop ad hoc networks. All the nodes between the source and destination exchange routing information through routing information accumulation [14]. It can enables dynamic, reactive, multihop routing between participating nodes wishing to communicate and adapt to the changing network topology and determine unicast routes between nodes within the network [11].

The Dynamic MANET On-demand DYMO routing protocol is a newly proposed protocol currently defined in an IETF Internet-Draft in its sixth revision and is still work in progress. The Dynamic MANET On-demand (DYMO) routing protocol enables reactive, multihop unicast routing between participating DYMO routers. The basic operations of the DYMO protocol are route discovery and route maintenance. DYMO is a successor of the AODV routing protocol. It operates similarly to AODV. The Ad-hoc on-demand Distance Vector (AODV) is basically reactive protocol which supports multi routing between nodes which are playing their roles to form an Ad-hoc network. AODV is the improved version of DSDV protocol, but the main difference is that AODV is reactive whereas DSDV is proactive. It has great advantages, for instance, for disseminating information through routes on demand basis requirement for maintenance is not necessary. DYMO can work as both a pro-active and as a reactive routing protocol [6].

DYMO routing protocol is a reactive protocol developed for MANET. All the nodes between the source and destination exchange routing information through routing information accumulation [14]. Route discovery and route maintenance are the two operations of the DYMO routing protocol. The originate node, in routing discovery, multicasts a RREQ to all the nodes immediately. In order to review the freshness of the route request, the RREQ consists of a sequence number to enable other nodes. Until the request reaches the target node, the network will be flooded with the RREQs. The originating node receives an RREP which is unicast hop-by-hop from the target node [19].

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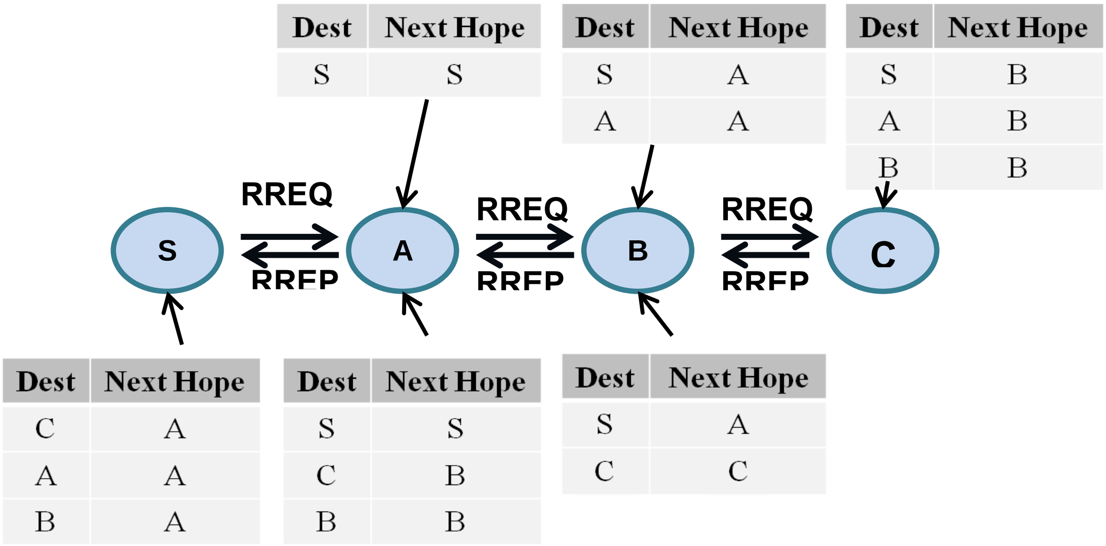

Figure 2.8: Routing table in nodes configured as DYMO routing algorithm [19]

As shown in Figure 2.3, in nodes configured with DYMO routing method, all nodes between the source and destination exchanges routing information via routing information accumulation. Consequently, when to receive re-sent packets, newly searching of routing path is not required for packet transmission which decreases the RREQ message overhead as RREQ messages for routing search are not saved from sending [14].

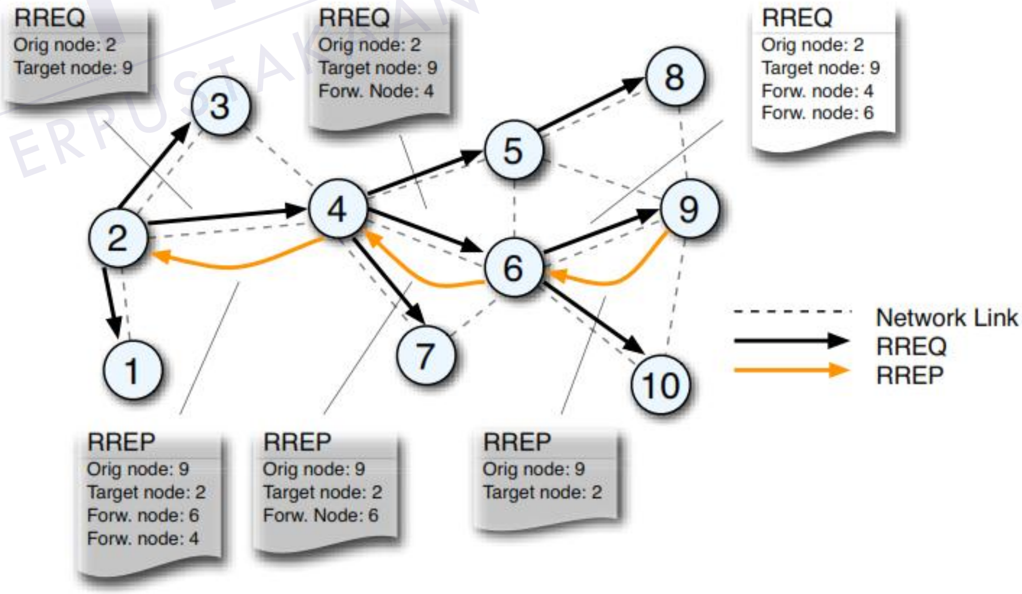

Figure 2.9: The DYMO route discovery process [24].

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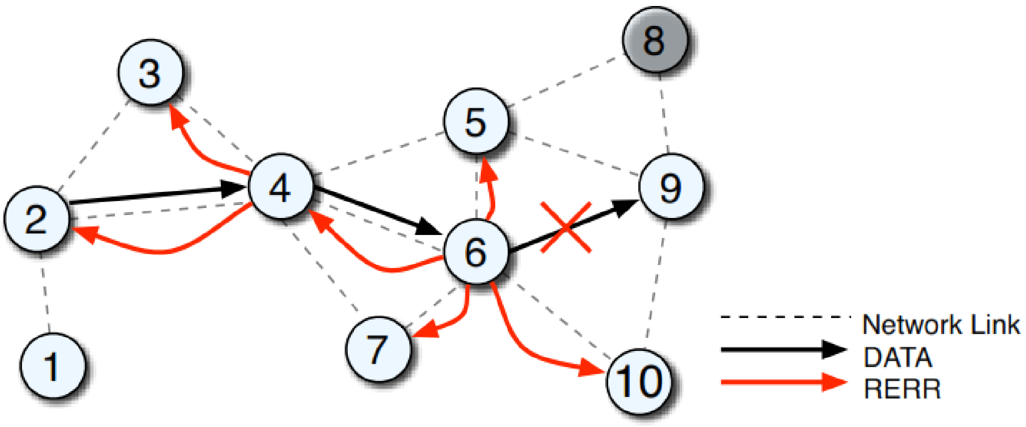

Figure 2.10: Generation and dissemination of RERR messages. [24].

I. Dietrich, C. Sommer, and F. Dressler [49] were developed a simulation model of DYMO for the network simulation environment OMNeT++. Based on the developed model, they performed several simulation experiments to analyze its performance. In their research, DYMO is able to set up and maintain unicast routes in IPv4/v6 scenarios by using the following mechanism:

i). In order to discover a new route to a peer, a node transmits a route request message (RREQ) to all nodes in range. This can be achieved by sending the message to a special link local multicast address, which addresses all MANET routers. When an intermediate node receives such an RREQ, it takes note of previously appended information, deducing routes to all nodes the message previously passed through. The node then appends information about itself and passes the message on to all nearby nodes. This way, the RREQ is effectively flooded through the MANET and eventually reaches its destination.

ii). The destination responds to the received RREQ by sending a route reply message (RREP) via unicast back to the node it received the RREQ from. As with the passing of an RREQ, this node again appends information about itself and takes note of all routing information contained in the RREP. With the help of the routing information previously obtained while forwarding the corresponding RREQ, the intermediate node is able to send the RREP to the start of the chain, until it eventually reaches the originating node. This node will now know a route to the requested destination, as well as routes to all intermediate nodes, and vice versa.

To efficiently deal with highly dynamic scenarios, links on known routes maybe actively monitored. An implementation may also choose to not actively monitor links, but simply drop inactive routes. Detected link failures are made known to the MANET by sending a route error message (RERR) to all nodes in range, informing them of all routes that now became unavailable. Should this RERR in turn invalidate any routes known to these nodes, they will again inform all their neighbours by multicasting a RERR containing the routes concerned, thus effectively flooding information about a link breakage through the MANET.

In [4], Muhammad Amin et all conclude from their research that analysis of DYMO and OLSR were carried out on the basis of throughput, optimal hop count and average network delay. Their simulation results show that DYMO performs well than OLSR in terms of throughput. Yogesh Chaba et all propose an efficient multi-path extension to DYMO with a load balancing technique for gateway selection in [13]. For gateway selection, a combined weight value is determined based on the metrics shortest distance, inter and intra MANET traffic load. The protocol is beneficial since the delay, average number of hops and routing overhead decreases efficiently. By simulation results in [13], their show that their proposed protocol achieves maximum packet delivery ratio with less delay and reduces the energy consumption of the nodes.

In [15], two routing protocols were compared. The first protocol is the reactive Dynamic MANET On-demand (DYMO). The second protocol is the proactive Optimized Link State Routing (OLSR). The comparison is based on the packet delivery ratio, the average end-to-end delay and the normalized routing overhead. The results show that the performance of DYMO is better than OLSR in both MANET and VANET networks. M. Quan-xing and X. Lei study DYMO routing protocol with respect to average end-to-end throughput, average end-to-end delay, packet delivery ratio, routing overhead and path optimality in [16]. They compare AODV and DYMO routing protocols and conclude that DYMO routing protocol performs better than AODV as it is being able to handle different mobility ranges and various traffic patterns.

QoS routing is a key MANET function for the transmission and distribution of multimedia services [52]. The main challenge of QoS routing in mobile ad hoc networks is to handle the topology changes appropriately. The performance of a protocol is greatly determined by its ability to adapt to these changes [50].

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S.Narendran and J.Satish Kumar discussed in their research about network routing protocols and its related quantitative performance metrics show that that DYMO provides better performance than others when compared in a given network topology with respect to Quality of Service (QOS) parameters. Based on their simulation analysis [17], it is established that DYMO owing to its hybrid characteristics of both reactive and proactive protocols, exhibit lesser delay and consequently more throughput, lesser packet loss and jitter.

DYMO protocols are designed for mobile ad hoc networks since DYMO is capable of handling dynamically altering mobile network patterns [18]. The routes between the source and destination are hence determined only when a route was required to be established. Being capable of handling on demand routes discovery and maintenance, DYMO can also adapt to wide ranging traffic patterns. DYMO can be typically utilized in a large mobile network consisting of large number of nodes where only a part of the nodes communicate with each other. DYMO is also memory efficient since it maintains very little routing information. In DYMO, only routing information that are pertinent to all active sources and destinations is maintained where as other protocols require entire routing information of all nodes with in a network.

To improve the robustness and adaptation to node mobility, ad hoc routing protocol uses as route selection criterion, the route reliability metric between end points. Among the routing protocols proposed, a large majority selects paths that minimize hop count. Whereas minimum hop count is the most popular metric in wired networks, in wireless networks interference- and energy-related considerations give rise to more complex trade-offs [8]. Therefore in [8], Liang Zhao and Ahmed Y. Al-Dubai [8] state a variety of routing metrics that has been proposed for MANET routing protocol providing routing algorithms with high flexibility in the selection of best path and offering a compromise between throughput, end-to-end delay, and energy consumption.

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2.3 Routing Metrics

Routing metrics are used to assign weights to routes by routing protocols to provide measurable values that can be used to determine how useful a route will be. In general, there are several routes between each pair of nodes in a network. Each of which has a different set of links with different costs. The route with a low cost should be selected by the protocol. Routing protocols use route metrics to make decisions about the best route to be selected between a pair of nodes. To perform an efficient route selection, good routing metrics are required for path computation. In order to gain a better understanding of the routing metrics, in this section several routing metrics will be briefly described which can be employed by the routing protocol for wireless mesh networks to find best possible paths.

Routing metrics are important as they contribute to the success of the MANET protocols. Selecting the right routing metrics to be incorporated in a protocol would determine the efficiency and the reliability of the protocols. In this review, the selected routing metrics that will be discussed are ETX, RTT, Hop Count, Node Connectivity Index (NCI) and SNR that implement in routing protocol.

There are some research have been done on the DYMO protocol for MANET related to the selected route metric in this research proposal, as found in studies conducted in [4] that involves a hop count (HOP) as routing metric. While a research conducted by Nadeem Javaidin [22], the ETX routing metrics have been tested in both reactive (AODV, DSR, DYMO) and proactive (DSDV, FSR, OLSR) protocols on Wireless Multi-hop Networks and as described previously MANET is part of the Multi-hop Wireless Networks. In the research that has been done by David [23], ETX also tested on three popular MANET ad hoc routing protocols, namely AODV, DYMO and OSLR. Another routing metric also was measured in [24] through an experiment has been done to measure the metric round-trip time (RTT) in DYMO protocol for the multihop ad hoc network. NCI as a mobility metric in MANETs was discussed in [50] where it has been observed about the performances of protocol QOSRGA. The SNR as a routing metrics also has been done in research [25, 38, 39, 40], where this routing metrics was measured also in MANET but it was implemented for DSR protocol and DSDV in [41] .

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i). Hop Counts (HOP)

Hop count represents the number of hops traversed by a packet between its source and destination and it is a widely used as a routing metric for Ad Hoc networks because of node mobility which leads to frequent link breakages [25]. It reflects the effects of the path length on the performance of an end-to-end flow. The path weight equals the total number of links through the path. This metric is used in most of the common routing protocols like OSLR and DYMO [4].

However, hop count does not take into account the interference in the network nor the differences of link quality between different wireless links, including the available bandwidth, transmission rates, link load, packet loss ratio, and so on [26,27]. It may choose paths which have a high loss ratio (the ratio of the data packets originated by the sources fail to deliver to the destination) and poor performance in terms of different metrics such as throughput, number of dropped packets, and end-to-end delay [21]. Douglas et al. explores the details of the performance of minimum hop count routing on a wireless test-bed and found that minimum hop count often finds route with significantly less throughput than the best available.

Muhammad Amin et all were compared the performance of hop count for DYMO and OSLR in [4]. They found that the reason that optimal hop count is less for OLSR than DYMO is that proactive protocols like OLSR are less affected due to frequent change in mobility and increased pause time due to stable routes and periodic updates. In OLSR, shortest possible hops are selected and long stable routing paths are used thus minimizing the overall optimal hop count value. DYMO on the other hand, uses multipath that allows considering more routing paths than OLSR resulting in greater hop count value.

This metric provides minimum hop-count routing. Link quality for this metric is a binary concept; either the link exists or it doesn’t. The primary advantage of this metric is its simplicity. Once the topology is known, it is easy to compute and minimize the hop count between a source and a destination. Moreover, computing the hop count requires no additional measurements. The primary disadvantage of this metric is that it does not take packet loss or bandwidth into account. For example, a two-hop path over reliable or fast links can exhibit better performance than a one-hop

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