Energy Aware Dynamic MANET On-demand (EA-DYMO)

Sumit Kumar Singh
Department of Computer Science & Engineering
Madan Mohan Malaviya Engineering College,
Gorakhpur-273010, U.P, INDIA

Shiva Prakash
Department of Computer Science & Engineering,
Madan Mohan Malaviya Engineering College,
Gorakhpur-273010, U.P., INDIA

Kapil Kumar
Department of Computer Science & Engineering,
Madan Mohan Malaviya Engineering College,
Gorakhpur-273010, U.P., INDIA

ABSTRACT
An important and essential issue for mobile ad-hoc networks (MANETs) is routing protocol design i.e. a major technical challenge due to the dynamism of the network. The work of this paper is inspired by the thought of taking account of several factors in wireless mobile ad-hoc networks (MANETs) routing design in a unified way. The rational of our inspiration is that most of the enhancements in DYMO protocol have been based on one criteria i.e. shortest path considered or multipath. There are several works in other On-demand routing protocols which considered some factors in a unified way. Therefore, we propose a routing mechanism i.e. "EA-DYMO Energy Aware Dynamic MANET On demand". In this routing mechanism, we would consider both the traffic load and energy aware path in a unified way. In this paper, we are modifying route selection procedure by taking the ratio of the energy factor as well as the average traffic load for each path, analysis and simulation we will consider as our future work.

Keywords
MANET; On-demand routing protocols; DYMO; Energy Aware;

1. INTRODUCTION
A mobile ad hoc network is a collection of mobile nodes equipped with wireless transmitters and receivers using antennas which may be Omni-directional (broadcast), highly-directional (point-to-point), possibly steerable, or some combination thereof. MANET is a self organizing and self configuring multi-hop wireless network, and this network topology changes frequently due to dynamic movement of the mobile nodes. Nodes in these networks utilize the same random wireless channel, cooperating in a friendly manner to engaging themselves in multi-hop forwarding. The nodes in the network not only act as hosts but also as router that route data to/from other nodes in the network. In these networks a wireless connectivity in the form of a random, multi-hop graph or "ad-hoc" network exists between the nodes. This ad-hoc topology may change with time as the nodes move or adjust their transmission and reception parameters.

Some of the main challenges of the ad hoc network are the basic routing mechanism, bandwidth limitations, battery power of the mobile nodes and other quality of service issues. Many routing protocols have been proposed till now. Routing protocols in ad hoc network are basically of two types the table driven type (the prototype type) and the on demand type (the reactive type). In table driven type, the routing table of each node is updated by the periodic exchange of routing information between the nodes. Therefore, the routing overhead increases due to these periodic exchanges. The table driven routing protocols are DSDV [8], WRP [12], CGSR etc. In contrast, the on demand type protocols create a route to a destination node only when there is a requirement by a source node. It has low overhead as compared to the table driven type. The on demand routing protocols are AODV [14], DYMO [1], DSR etc.

The traditional routing protocol which are used in wired network are not efficient for wireless ad hoc network because ad hoc network constitutes of battery powered mobile devices with limited energy resources. The traditional routing protocol did not consider the node's energy consumption and hence there is a need to design an energy aware algorithm to improve network performance. In this work, we focus on the DYMO (Dynamic MANET On-demand) routing protocol, to make an efficient route selection on the basis of remaining energy level and average traffic load of the each node.

1.1 DYMO Overview
DYMO (Dynamic MANET on demand) routing protocol is a successor of AODV [14]. DYMO routing protocol draft [1] states that DYMO enables reactive and multiple hop unicast routing among the DYMO routers. DYMO has unified packet format, it also has simplified RERR algorithm and multiple interface utilization. The most attractive specification defined in the DYMO draft is the internet connectivity. DYMO operates very similar to the AODV. The basic operations of the DYMO are route discovery and route maintenance.

In a route discovery process the originator node broadcasts the RREQ message throughout the network to find the target node. During the dissemination process which is done hop by hop, each intermediate node makes a record of the route to the originator node. When the target node receives the RREQ, it responds with a RREP message sent hop by hop towards the originator node. Each intermediate node receiving the RREP creates a route to the target node, and the RREP is unicast towards the originator. When the RREP is received by the originator node then the path is established between the originator and the target node in both the directions.

Sequence numbers are used to avoid routing loops and to obtain fresh information about routes. In order to react to network changes all nodes monitor their routes. Route maintenance scheme has two components; (1) extension of route lifetime in case of the successful delivery of packets, and (2) if received packets belong to an unavailable route, a RERR message is sent to report link breakage to the originator of the data packets that were forwarded over the broken link. When the originator node receives the RERR message, it deletes the invalid route. If the originator node later receives a packet for forwarding to the same target node, it will need to perform route discovery again for that destination.

DYMO acts as source routing with a path accumulation capability i.e. when an intermediate node forwards RREQ and RREP it appends its address to the control messages. Thus, the other nodes which will receive the control packets will come to know about the path towards the forwarding node. The path accumulation feature can reduce the future route discoveries but it also gives rise to the packet bloat problem. This routing protocol is best suitable for the devices having small memory because the nodes have to store only small amount of information. The DYMO routing algorithm can also work on the other layers rather than the network layer.

This paper is organized as follows: Section II will introduce Literature Review, Section III introduces proposed work. Section IV will provides a deep discussion and analysis of EA-DYMO. Our paper finally concludes in section V with an outlook to future work.

2. LITERATURE REVIEW

Most of the energy related enhancements have been done in On-demand routing protocols. 'Yonghui Chen' in [7] has proposed an energy saving routing multipath protocol EEAODV. This approach is based on residual energy and stability of the nodes. The choice of the node depends on residual energy and good mobility. The authors have also compared and simulated the DYMO protocols with different reactive protocols. In [13] a detailed comparative study of two On Demand routing protocol AODV and DYMO has been done, in order to find out most appropriate protocol for rescue task operation. The result shows that DYMO has better performance than AODV and DYMO might support workload during rescue tasks in disaster situation enabling to maintain continual operation and communication. The author in [9] has proposed a comparative study of DSR and DYMO in two building environments such as factory and office. They showed that DSR has better performance than DYMO from PLR (Packet loss rate) point of view.

Many enhancements have been done to improve the performance of DYMO. These enhancements have been made by modifying route discovery mechanism on the basis of different parameters of MANET. The author in [2] presented DT-DYMO which uses a route discovery mechanism in order to find the destination or nodes that are likely to be able to deliver the message in future. It provides faster delivery than opportunistic message passing scheme that rely on delivery likelihood estimation. However, despite the good performance DT-DYMO could not solve all problems that occur in highly dynamic network. Multipath routing is a technique of using multiple alternative paths through a network which can yield a variety of benefits. The authors in [11] have given multipath extension to the DYMO routing protocol in their work. They focus on simple algorithm to solve the cut-off problems as compared to the previous solutions used for the AOMDV. In ad hoc network maintaining multiple paths can be favorable. The path can be used at the same time for load balancing or using alternative paths when primary path fails. In [6] DYMOM is proposed which enables DYMO to use more than one route. The authors have developed a routing mechanism in which more than one node-disjoint route towards the same destination.

Communications in mobile ad hoc network usually requires multi-hop routing. AODV is a single path routing protocol. In [4] efficient AODV routing is proposed. This protocol selects route on the basis of traffic load on the node and resets path as the topology changes. And it also enhances route discovery mechanism which ensures shortest routing path. Sharing of load decreases the network traffic load which directly leads to the decrease of overflowing of queuing buffer and packet loss. Hence packet delivery ratio and throughput is increased. Proposed protocol is more efficient for transmission that requires a link for longer period of time. In [3] authors proposed EEAODR algorithm which increases network life by balancing the energy load among nodes, so that a minimum energy level is maintained. The network longevity is also increased by distributing energy consumption. An adaptive load balancing approach for ad hoc network [5] is an effective scheme to balance the load and elevate congestion in the network. Routing protocol with this approach can evenly distribute the traffic among the nodes and reduce packet latency and routing overhead. Many routing protocols have been proposed for MANET, none considered minimum contention time and load balancing simultaneously. In [10], MCL is use to select a route with minimum contention among several possible routes between source and destination, intermediate nodes do not reply with RREQs in the route discovery procedure.

The study of literature gives an insight of different approaches of routing designed for MANET in order to achieve optimal performance in a given network scenario. After in depth analysis of the literature, it is clear that due to varying nature of MANET, no single routing protocol works efficiently in all network conditions. As most of the optimization available in AODV should also be applicable to DYMO as well. We will discuss the proposed routing protocol in next section.

3. PROPOSED ROUTING PROTOCOL

As per above literature survey, motivates us to develop a new load and energy aware Dynamic MANET On-demand (EA-DYMO) routing protocol, to make an efficient route selection on the basis of remaining energy level and traffic load of each node. In this work, we define the energy factor as the ratio of the remaining energy level over the initial energy level of a node. And also derive a Path Selection factor as the ratio of the energy factor and the average traffic load factor. The route having the highest value of path selection factor will be chosen for data transmission.

3.1 Description of EA-DYMO

EA- DYMO is a routing mechanism which considers energy conservation and traffic load awareness together. For the energy model we define several terms.

EF_j : Energy factor of node j

EA_j : Energy currently available of node j

EC_j : Consumed energy of node j

TE_j : Total initial energy of node j

N_{sdi} : Set of nodes on the i^{th} path from source s to destination d

Energy factor of node j is given by the following expression

$$EF_j = EA_j / TE_j \quad (1)$$

The energy currently available in equation (1) is defined as:

$$EA_j = TE_j - EC_j \quad (2)$$

Each time a node sends either data or control packet, the energy consumed is subtracted from the initial energy of the node.
Then, energy factor is calculated on the basis of equation (1) and it is maintained by each node.

$$EF_{sdi} = \min (EF_j) \quad (3)$$

And EF_{sdi} means energy factor of a specific path i from source s to destination d. The EF_{sdi} will be chosen as a factor for route selection. The path with the greater value will be chosen as the route to transmit data.

Similarly, for the traffic load model we define some terms for analysis,
LF_j : Traffic load factor of node j
CQ_j : Currently available network interface queue size of node j
TQ_j : Total maximum interface queue size of node j
DQ_j : No. of data packets in the interface queue of node j
The traffic load factor is given by the following equation:

$$LF_j = DQ_j / TQ_j \quad (4)$$

Where, $DQ_j = TQ_j - CQ_j$ (5)

Traffic load factor in equation (4) is the percentage of the network interface queue that is occupied. The default maximum size of the network interface queue is 25.
Now, the LF of all the nodes along a valid path are added together and divided by the no. of hops, to obtain the average traffic load factor LF_{sdi} of the path.

$$LF_{sdi} = \frac{\sum_{j \epsilon N_{sdi}} LF_j}{N_{sdi}+1} \quad (6)$$

No. of hops in path i = $N_{sdi} + 1$
The LF_{sdi} considers the occupied capacity of the network interface queue as indication of the traffic load of the path. A lower value LF_{sdi} indicates that the route has lower congestion to handle. Such paths should be chosen as it avoids the utilization of congested paths which leads to higher number of packet loss and longer delay. The integrated model is the combination of both the traffic factor as well as the energy factor.

These two factors are combined and use to calculate the path selection factor on the basis of following equations:

$$PS_{sdi} = EF_{sdi} / LF_{sdi} \quad (7)$$

The path with the highest PS_{sdi} value will be selected as the route for data transmission.

4.2.1 At the source node

When a source node wants to communicate with target node for which it has no route in its routing table then it initiates route discovery process, and broadcast RREQ packet to its neighbors. The RREQ packet will carry two additional information energy factor and load factor.

4.2.2 At each intermediate node

When the neighbor node receives the RREQ message it will calculate the Load factor i.e. the number of packets currently stored in the queue and divide it with the size of queue and add it to the reserved field in RREQ message. It will also calculate the value of Energy Factor and compare it with the energy field in RREQ packet.

if
(EF in RREQ field > EF of current node && EF of current node ≥ 30%)
then
(Update value of RREQ EF field with current node's EF value)
else
(No update required in RREQ EF field)

4.2.3 At destination node

When a destination receives route request it will strip the information in the LF and EF field of the RREQ and update its routing table.

The destination will now calculate the average traffic load of the path of each RREQ received by the destination on the basis of equation (6). Now destination will finally select the most energy efficient and less congestion path by the path selection factor by equation (7). The value of $PS_{sdi}$is bigger, the efficient route is replied by the destination node by RREP to the originator of the RREQ. We present discussion and analysis in next section.

4. DISCUSSION AND ANALYSIS

As above described EA-DYMO, we modified the basic DYMO route discovery mechanism, by calculating load factor (LF) and energy factor (EF) on each node, during the process of route discovery. When a source node wants to communicate with another node for which it has no routing information in its routing table then route discovery process starts. Source node broadcasts RREQs message to its neighbors.

When a neighbor receives RREQ message, it will calculate the load factor and add its value to the reserved field of the RREQ message and it also calculates the value of energy factor and compare it with the energy field in RREQ packet. This process is done at each node in the route to the destination. At the destination average traffic load factor is calculated by dividing load reserved field value with the number of hop counts.

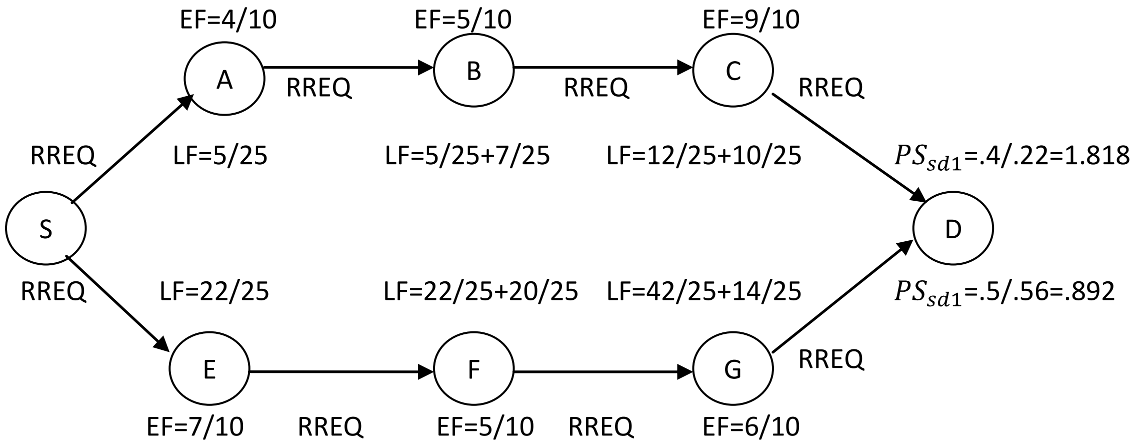

Figure1

Figure 1 is explaining the whole process. In this figure the value of EF and LF indicates the energy factor and load factor of node respectively. Initial energy and queue size are constant i.e. 10 and 25 respectively.

The value LF_{sdi} and EF_{sdi} finally reach the destination and then it will calculate the path selection factors, PF_{sdi}. The destination compares the PF_{sdi} values with all requests it received with same sequence number and unicast RREP message back to the path whose PF_{sdi} value is higher.

So, in figure 2, the path S-A-B-C-D is selected as the route from source to the destination for the transmission. By selecting route in this way we overcome the limitation that the node with more load and low energy will come in the active route.

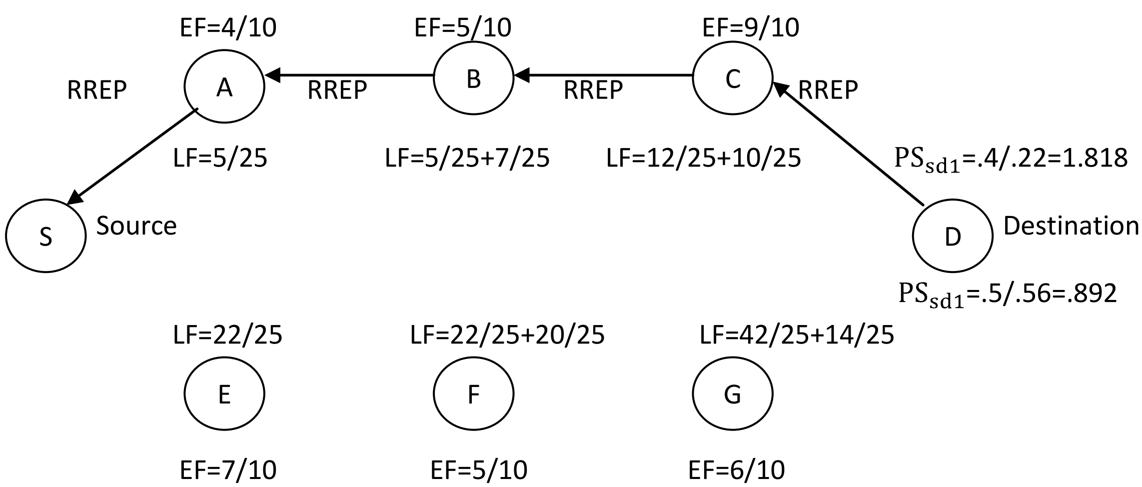

Figure 2

There are lots of question to be answered like: what happened if an intermediate node have fresh route to the destination, what happened if a RREQ have lesser no. of hops but less energy value and more load values etc. To tackle with all such questions mentioned above what we did is: At the destination the value of the load factor in the reserved field is divided with the no. of hop counts that produces average load on each node in the route. The value of EF in reserved field is divided by the average load factor to obtain the PS_{sdi} value. There is no gratitude reply to the source is produced by intermediate node.

5. CONCLUSION AND FUTURE WORK

In this model paper we proposed EA-DYMO, a protocol with enhanced route discovery mechanism which takes into account the energy and load factor to select the most efficient route. Thus, rather than using the traditional metrics such as delay or hop count, we believe the node's energy and traffic load to be taken in to account as routing metric in a unified way which can give the better performance in MANET. Our future research work is to simulate EA-DYMO and to obtain the performance result in terms of the packet delivery ratio, network lifetime and the average end to end delay.

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