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QoS Improvement in Multi-Path Routing Protocol for Manet

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Abstract: A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure-less network of mobile devices connected without wires. The primary characteristics of MANET are the dynamic topology and the limited battery life of mobile nodes. Due to its battery constraints causes packet loss and the re-initialization of route discovery process which leads to high bandwidth utilization, increase in the delay and decrease in the throughput. In this paper, we propose a novel power and delay aware routing protocol for wireless Ad Hoc networks. The aim of our proposed routing protocol is discover more optimal paths from a source to a destination node in terms of remaining duration of battery and also find multi-paths that assure delay and bandwidth. These new set of requirements in which operate together is called as Quality of Service (QoS). We show through simulation that our proposed routing protocol called Power and Delay aware Multi-path Routing Protocol (PDMRP) performs better than Optimal Path Routing Protocol (OPR) and the Modified Ad- hoc On-Demand Distance Vector (MAODV) routing protocols in terms of throughput, end-to-end delay and loss rate. We change the AODV protocol in NS-2 simulator so that it supports the power module. We add the power class to the neighbor and destination nodes. Therefore, the duration of each node in this protocol decreases when it sends or receives a packet. This change is made on the AODV protocol to become similar to the two other routing protocols (The three protocols support the power module).

Key words: AODV · OPR · Delay · Power · PDMRP

INTRODUCTION

A Mobile ad hoc network [1] is a group of mobile nodes that can dynamically change into a random and temporary topology to form a network without using preexisting infrastructure. In particular. MANET has no base stations: a node directly communicates with other nodes within its coverage range through multi-hop route. Each node, not only acts as a host and also acts as a router, forwarding data for other hosts.

The challenging task for mobile ad hoc networks is design a routing protocol due to the dynamism of the network. There are two types of protocols in MANET and it may be categorized as: reactive protocols (on-demand) and proactive protocols (table-driven). Reactive protocols seek to set up routes on-demand manner and find the link in order to send out and accept the packet from a source node to destination node. Route discovery process between source and destination nodes by flooding the route request (RREQ) packets throughout the network and get the Route reply (RREP) from the destination node. Examples of reactive routing protocols such as dynamic source Routing (DSR), ad hoc on-demand distance vector routing (AODV). Each node in the network maintains routing table for the broadcast of the data packets and want to create connection to other nodes in the network before data sending process.i.e. routes are pre-determined. If any node needs to send any data to another node, the path is well known, therefore, latency is low.

In [2], Samarth H. Shah, Klara Nahrstedt was proposed a new protocol called as QoS aware routing protocol to overcome the dynamic topology problems. The location of nodes can be updated by using speed or virtual movement of a node. This protocol proposes a new way of the estimated bandwidth to respond to network traffic.

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In [3], Chen *et al*. presented a congestion-aware routing protocol for mobile ad hoc networks (CARM), which uses a metric incorporate data-rate, channel delay and buffer delay and retransmission count. These metrics are utilized to select highest throughput links, avoiding the most congested links or mismatched links. The CARM carries the entire route node sequence for every packet like DSR.

In [5], Zafar *et al*. proposed a Shortest Multi-paths Source (SMS) routing protocol which is based on DSR and Split Multi-paths Routing (SMR) [6]. This proposed routing protocol increases the number of stable paths between the source and the destination node. It achieves shortest paths and it allows more number of fast recoveries from route breaks. However, these algorithms mentioned above may result in a fast reduction of the battery energy of the nodes in a large amount heavily-used path in the network. In reality, routing of packets is an important power consuming process because it involves more number of Route discovery process during data transmission. The universal consent is that routing protocols must optimize energy consumption during the routing activity specified the inadequate battery power accessible in mobile nodes.

In [7], Dhurandher *et al* proposed an energy-efficient routing protocol for mobile ad hoc network to minimize the energy consumption and increase the networks consist, they minimize active communication energy to send or receive packets and maintains energy load among nodes in the network. It provides high result of maintaining energy level compared to other routing protocols in MANET.

In [8], Hyungseok Choi *et al*. proposed on power-aware routing protocol and it provides enhanced performance in terms of link breakage. In reality, it discover route between the source and the destination in terms of residual energy of each node. In [9], Sharma and Kush proposed a power-aware routing protocol. This protocol is included with the Ad hoc On-Demand Distance Vector (AODV) protocol [10], which will be discussed in the next section. The enhanced protocol allows a node to keep route to a destination with more stable path selection. It insures fast selection of routes with faster recovery and minimal efforts. In [7], [8] and [9], the authors include the parameter of energy of each node when a source finds a path to a destination, but they do not consider other parameters such as QoS requirements in terms of data rate and delay as in [2] and [5].

Now, we include some advantages of these existing routing protocols and we propose a new routing protocol called Power and Delay aware Multi-paths Routing Protocol (PDMRP). This protocol is implemented in Ad Hoc networks by a source to discover optimal paths to the destination. It is based on Optimal Path Routing Protocol based on Power Awareness (OPR) [11] routing protocol, which will be described with its boundaries below. Our OPR protocol will find multi-paths with minimum hop-count and highest residual energy. Also, these selected multi-paths must convince the QoS parameters in terms of bandwidth.

To estimate the performance of our proposed routing protocol, we compare it with the OPR routing protocol and the modified AODV routing protocol. The remaining part of this paper, we review the AODV protocol and route discovery process. Then, we describe the OPR routing protocol, format of RREQ and RREP with diagram specifications, examples of battery life of nodes and its functionalities. Finally the performance evaluation results of our routing protocol and concluded with various QoS parameters.

Aodv Protocol: AODV is an on-demand routing protocol for mobile ad hoc networks [10]. Route Requests (RREQs), Route Replies (RREPs) and Route Errors (RERRs) are the types defined by AODV.RREQ messages are used to initiate the route finding process.RREP messages are used to finalize the routes. RERR messages are used notify link breakage in an active route. When a source node wants to send a message to destination node, it broadcasts an RREQ packet to its neighbors until it reaches to the destination node.When an intermediate node receives this packet and, it checks the destination address, if the intermediate node's address does not match with the address of RREQ, it increments the hop-count in its routing table and re-broadcasts the RREQ packet. Otherwise, it generates a RREP packet and sends it to the source node. Now the source receives the multiple RREP packets from the same destination, in which it selects active route by using least hop count through routing table information and it saves the route and begins data transmission. If a node detects a link failure in an active route, it sends a RERR packet to inform the remaining nodes about this problem. One distinctive feature of AODV is its use of destination sequence number for each route entry. The routes between source and destination nodes are discovered and the active route is used to data transmission process.

The RREQ message format for AODV protocol is shown in Figure 1.

Type	J	R	G	D	U	Reserved	Hop-count
RREQ ID							
Destination IP Address							
Destination Sequence Number							
Originator IP Address							
Originator Sequence Number							

Fig 1: RREQ message format for AODV Protocol

Type: Set to 1, it specifies type of packet
J: Join flag; which is reserved for multicast.
R: Repair flag; which is reserved for multicast.
G: Gratuitous RREP flag, check it should be a unicast.
D: Destination flag.
U: Unknown sequence number; it denotes destination only respond to this RREQ.

Reserved: It is set to 0; ignored on reception

Hop Count: It denotes the number of hops from the source node to the node handling the request

RREQ ID: It denotes the sequence number uniquely identifying the particular RREQ when taken in conjunction with the source nodes IP address

Destination IP Address: It denotes the IP address of the destination for which a route is desired

Destination Sequence Number: It denotes the last sequence number received by the originator for any route towards the destination,

Originator IP Address: The IP address of which node originates the route request.

Originator Sequence Number: It denotes the current sequence number to be used in the route entry pointing towards the source of the route request.

Opr Routing Protocol: The aim of the OPR protocol is providing the QoS in terms of bandwidth and increase throughput by selecting optimal path. There are two reasons link failure may arise, one for arbitrary movements of node and another for limited battery power. When the optimal route is selected where delay is reduced and remaining life time of the battery also smaller.

To discover the optimal path, the source node broadcasts a RREQ packet to the destination node through the neighbor node.

The RREQ Message format of OPR protocol is shown in Figure 2.

RBW	ML	TTL	seqnum
Source Address			
Destination Address			
Address 1			
……..			
Address n			

Fig 2: RREQ message format for OPR protocol

RBW: It denotes the required bandwidth for data ransmission
ML: It denotes the minimum remaining life of the path
TTL: Time to live
Seqnum: It denotes the unique sequence number of RREQ
Source Address: It denotes the address of the source node
Destination Address: It denotes the address of the intended destination node,
Address i: It denotes the address of an intermediate node of the route.
Address 1---- Address n: Address of visited nodes.

RREQ Packet Contains Two Major Fields: Required bandwidth and battery life. Battery life is calculated by remaining time left and it is helpful in discovery of optimal paths. When an intermediate node receives an RREQ packet it checks the own address matches with the destination address of the packet. If both address matches, it sends a RREP packet along the reverse route. Hence, Source node receives multiple routes from the same destination, but it select the optimal path in terms of bandwidth and battery life time of the nodes. Otherwise, it checks first the availability of the required bandwidth. If the sufficient bandwidth for data transmission is not available, it drops the RREQ packet. If there is sufficient bandwidth for data transmission, the intermediate node decrements the time to live (TTL) by 1. TTL reaches value of 0; the intermediate node drops the RREQ packet and sends an error message to the source node.

After that, the node will estimate the minimum path life by comparing its own residual life with the value of the ML Field. Node will reset ML field and rebroadcast the RREQ packet. Before rebroadcasting the RREQ packet, the node appends its address in this packet and maintains in its routing table some information like source address, the destination address, the sequence number of RREQ and minimum life of the route. In the OPR routing protocol, if any intermediate node receives multiple RREQ packet from the same source, it compares that the ML of these two packets. If the ML field is greater than the previously forwarded RREQ packet, then the node will re-broadcasts this packet. Else, the RREQ packet is dropped.

After getting the first RREQ packet, the destination node waits for the reception of other RREQ packets for a stipulated amount of time. This helps for the destination node selects the best and optimal path where the chances for link breakage due to limited battery life. Then, it compares the ML fields of all received RREQs packets and selects the greatest value of ML field and it drops the remaining RREQs packets even though the difference between the ML value of the selected RREQs and the other dropped RREQ value is small. The destination node selects longest path because the OPR protocol does not take into account the end-to-end delay. In order to evaluate the functionality, we take an example of an Ad Hoc networks with eight nodes (see Figure 3).

Consider that N1 is the source node and N8 is the destination node. The source N1 broadcasts the RREQ packet to all other neighbor nodes in order find the route between N1-N8. Hence, the destination Node N8 will receive two RREQs. The first path is (N1 - N3 - N5) and the value of ML equals to 40 energy units (eu). The second path is (N1 - N2 - N4 - N6 - N7) and the value of ML equal to 41 eu. The OPR protocol satisfies QoS parameters in terms of bandwidth and presumes in this example that the necessary bandwidth is available.

According to the SPR protocol, N8 will choose the second path (N1 - N2 - N4 - N6 - N7) as it is more stable in terms of remaining battery life although (N1 - N3 - N5) is shorter than this selected route and the difference between their remaining life is very small (41 - 40 = 1 eu). So this protocol has serious problem in terms of delay since it does not select the shortest path.

Also, in the OPR protocol the destination node finds one route for data transmission. If there is any fault or link break in this route, the route discovery process is triggered. So it leads to high bandwidth consumption, delay and decrease in the throughput. To enhance the OPR routing protocol and taking the end-to-end delay parameter by choosing the shortest routes between the source and the destination nodes, we propose a new routing protocol named PDMRP.

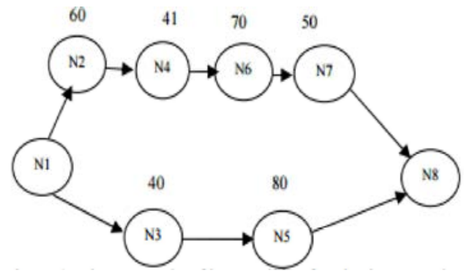

Fig 3: First example of battery life of nodes in network

Proposed Routing Protocol: In order to overcome some limitations of the OPR routing protocol, we propose a new routing protocol called Power and Delay-aware Multi-path Routing Protocol (PDMRP). The aim of our PDMRP is to select multiple paths between source and destination with the maximum lifetime in the network without performance affected by delay time. To achieve this goal, first we calculate the Cost called "C" of each route by using the following equation:

$$C= ML/NH \quad (1)$$

Here NH denotes the number of hops in the route.

Our scheme base on the same principle of OPR protocol, but we change few steps as follows:

- When an intermediate node receives multiple RREQ packets from the same source, it calculates the C value for each RREQ packet by using equation (1). It re-broadcasts the packet with the maximum value of C and drops the other packets.
- After getting the first RREQ packet, the destination node waits for receiving other RREQ packets from different paths for a stipulated time. Then, it replies the RREP packet to the corresponding source node. This helps the source node to find the shortest and the most optimal path and maintaining alternative paths and it will be used whenever primary path does not becomes functional (for example when link break or node failure occurs),
- While getting all RREP packets, the source selects the primary route by using greatest C value. Then, all other routes are considered as alternative routes. Firstly, the data transmission uses only the primary path and in case there is any type of fault in this path, the source node can quickly exchange to the next shortest and most optimal route.

In order to realize the functionality of the proposed protocol, we choose the example of the ad hoc network exposed in Fig 4 that consists of 16 nodes.

Assume that source node will be the N1 and destination node will be N10. According to the OPR protocol, the destination node choose the following path (N11 - N12 - N13 - N14 - N15 - N16). Actually, this path has the highest minimum residual power that is equal to 60 eu. Though, our proposed method considers both the residual power and the number of hops. For that cause, the source calculates the C value of each route and then it chooses the route with the highest value of C as a primary route. In this case, the source node will choose a path (N8-N9-N10) as a primary route because its C value is the greatest (40/2 = 20 eu). Note that path (N3 - N4 - N5 - N7 - N10) will be the secondary route and finally path (N11 - N12 - N13 - N14 - N15 - N16 - N10) will be considered as the third route.

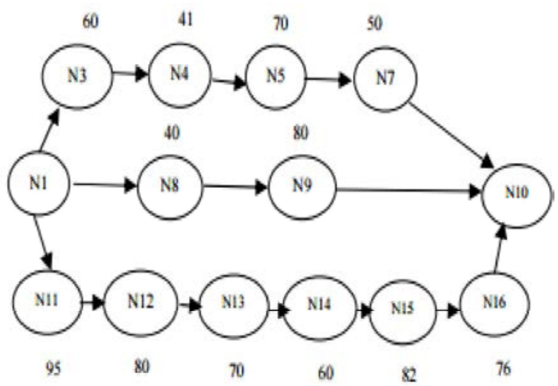

Fig. 4: Second example of battery life of Nodes in Network

Simulation and Evaluation: To estimate our proposed routing protocol (PDMRP), a simulation study is conducted by using the NS-2 simulator [12]. We compare this proposed protocol with the OPR and the modified AODV (MAODV) routing protocols. The simulation is carried out for 100 seconds and using a size of the topology is 1000 meter * 1000 meter. We use the two Ray ground as a model of propagation and the Constant Bit Rate (CBR) as a traffic type. The Parameters used in our simulations are listed in Table I.

Table 1: Simulation Parameters

Parameters	Value
Protocols	MAODV, OPR and PDMRP
Traffic Type	CBR
Number of traffic	Between 4 and 12
Simulation Duration	100 seconds
Packet Size	512 bytes
Simulation Area	1000 m x 1000 m
Number of mobile nodes	30
Queue length	250
MAC protocol	MAC/802.11
Mobility model	two Ray ground

In this part, we estimate the performance of the different routing protocols using the following metrics:

- Throughput: It denotes the average number of bits received by a destination node per second.
- Loss rate: Denotes the average number of bits lost per second.
- Mean end-to-end delay: Denotes the average of the difference between the time of the packet delivery to the final destination and the creation time of this packet.

Figure 5 represents the throughput as function of the number of traffic flows. We see that the throughput increases for the three routing protocols when the number of flows increases.

We also noticed that our proposed protocol provides the highest throughput. Because in PDMRP protocol, when there is a problem in the active (primary) route, the source continues sending packets to the destination by quickly exchanging to a secondary route but the MAODV and OPR protocols have to initialize the routes discovery process. Moreover, our proposed protocol takes into account the life time as well as the number of path hops in order to cleverly share energy consumption between stable nodes (having higher battery life).

Figure 6 shows the throughput as a function of the number of traffic flows. We see that when the number of traffic flows increases, the throughput increases. Indeed, the traffic flows follow the most stable and shortest paths.

Figure 7 represents the end-to-end delay as a function of the battery life. In Figure 8, this metric is represented as a function of the number of traffic flows. We see that the PDMRP protocol outperforms the MAODV and OPR protocols by providing the lowest end-to-end delay. This is due to the tacking into account of the number of hops when selecting the primary route using equation (1).

Figure 9 represents the loss rate as a function of the battery life. In Figure 10 this metric is represented as a function of the number of traffic flows. As we show in this two figures the loss rate increases with the increase of battery life as well as with increase of the number of traffic flows. However, for our proposed protocol, the value of the loss rate is the lowest. This is because in the PDMRP protocol, the source selects multi- paths and when there is any problem in the primary path it switches to the secondary path. Thus, the probability of the loss of packets is less than for the MAODV and OPR protocols.

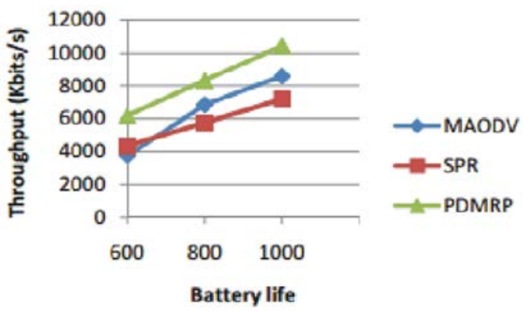

Fig. 5: Throughput versus battery life

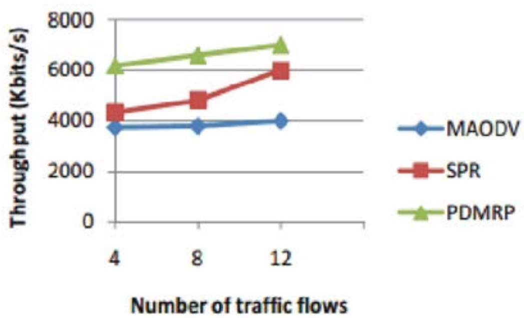

Fig. 6: Throughput versus number of traffic flows

Figure 7 represents the end-to-end delay during progress of the simulation time. But in Figure 8, this metric is represented as a function of the number of traffic flows. As indicated by the two figures, the PDMRP protocol is more favorable as its delay is low than the MAODV and the SPR protocol. This is because in our proposed protocol the packets follow the shortest path.

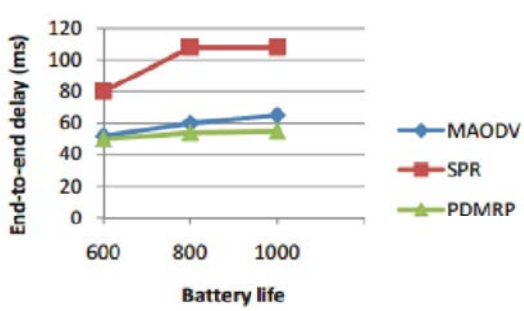

Fig. 7: End-to-end delay versus battery life

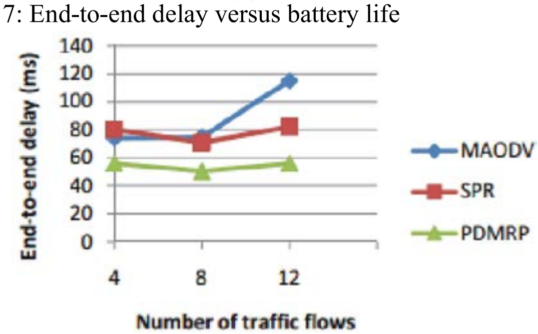

Fig. 8: End-to-end delay versus number of the traffic flows

Figure 9 represents the loss rate during the simulation time. But, in figure 10 this metric is represented as a function of the number of traffic flows. As we see in these two figures, the loss rate increases with the increase of the number of traffic flows. But for our proposed protocol, the value of the loss rate is the lowest.

This is because in the PDMRP protocol, the source selects multipath and when there is any problem in the primary path it switches to the secondary path. Thus, the probability of the loss of packets is less than for MAODV and SPR protocol.

The simulation results show that the proposed protocol significantly outperforms the OPR and MAODV protocols in terms of throughput, end-to-end delay and loss rate. Indeed, PDMRP provides the shortest end-to-end delay because it considers the number of hops when selecting the primary path. Further, our proposed protocol performs better in terms of throughput and packet loss as it takes into account the battery life of nodes and therefore chooses a stable path. Moreover, it can rapidly use secondary paths when a node or a link fails. More investigations are still needed to evaluate the performance of our routing protocol for interactive real time applications such as Voice over IP (VoIP). It is also interesting to improve PDMRP in a manner that the source can use all or part of the selected multi-paths to communicate with the destination in order to increase the throughput while extending the battery life of different nodes.

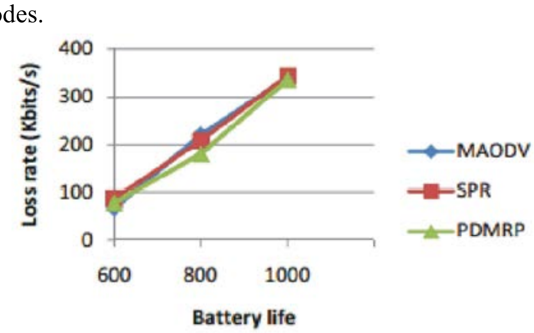

Fig. 9: Loss rate versus simulation time

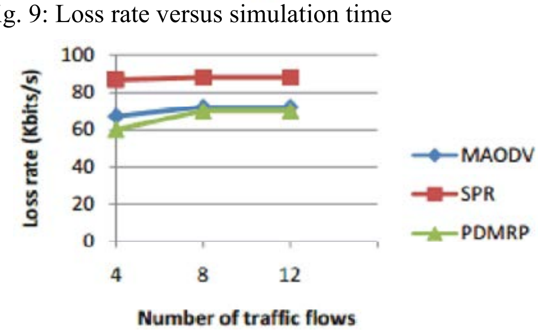

Fig. 10: Loss rate versus number of traffic flows

CONCLUSION

The power is a major constraint in ad hoc networks since the nodes operate with limited battery life. Hence, the routing protocols in this type of networks must be developed to consider power aware as a primary objective. Also, the support of QoS requirements in terms of delay and bandwidth becomes a challenge due to the dynamic nature of ad hoc networks.

In this paper we proposed a new routing protocol for ad hoc networks. Our proposed protocol does not consider only the battery power as a major challenge, but it also aims to satisfy QoS requirements (delay and bandwidth). Moreover, our routing protocol keeps backup paths in order to rapidly switching to operational routes when problems occur.

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