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Energy Efficiency of Multipath Routing in Mobile Ad Hoc Networks

B. Kumar

Department of Computer Science & IT, MJP Rohilkhand University, Bareilly, India

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***Abstract*—** Mobile ad hoc networks (MANETs) are composed of battery operated devices. These devices have limited battery capacity, which makes energy a scarce resource in MANETs. Energy conservation is crucial in such networks. Even though a node may not have any message of its own to transmit, its battery is drained when it acts as a router and forwards packets for other nodes. The frequent route discovery attempts in dynamic networks can affect the performance adversely. Multipath on demand protocols try to alleviate these problems by computing multiple paths in a single route discovery attempt. In order to utilize the limited energy source effectively and extend the lifetime of the network, routing protocols should be energy efficient. The energy consumption is not only affected by the network operations but also by the mobility pattern of the nodes. In this work, a well-known multipath routing protocol ad hoc on demand multipath distance vector (AOMDV) is evaluated for the energy consumption under different mobility patterns. The evaluation is done under different mobility models and results are reported for various parameters.

***Keywords*—** AOMDV, Energy, MANET, Mobility model, Routing.

I. Introduction

A mobile ad hoc network (MANET) [1] is formed by mobile nodes, where each node can act as an end-point as well as a router. These networks are dynamic and self-configurable infrastructure-less multi-hop networks. The nodes which are not in direct range of each other communicate through some intermediate nodes. These types of networks are well suited for use in rescue operations, military operations, conferences, and vehicular networks etc., where a permanent infrastructure is not available.

Routing is an important operation, which is responsible to discover a path from source to destination for end-to-end delivery of data packets. A number of routing protocols have been proposed based on different approaches. Some prominent protocols are ad hoc on demand routing (AODV) [2], destination sequence distance vector (DSDV) [3], dynamic source routing (DSR) [4], and location aided routing (LAR) [5] etc. However no one protocol works well for all kind of scenarios including network traffic conditions, mobility patterns, network sizes, and energy consumption, etc. Energy consumption of the nodes is crucial for the lifetime of a battery operated network. It is important to reduce energy consumption to keep network alive for longer times. The multipath routing tries to minimize the operations involved in routing process for preserving network resources. Ad hoc on demand multipath distance vector (AOMDV) [6] is a well-known multipath routing protocol for MANETs. It discovers multiple paths between end nodes during each route discovery to reduce the overhead.

Mobility patterns affect the network performance in multiple ways such as distance between nodes, number of intermediate nodes, need of route discovery, etc. and energy consumption in turn. In this work various mobility models are used to analyze the impact of mobility on energy consumption in routing. The rest of the paper is organized as follows. Section II presents the related work, the mobility models used in the experiments are briefly described in Section III, the methodology used is given in Section IV, the experimental results are discussed in Section V, and finally Section VI concludes the work.

II. Related Work

Singh et al. [7] analyzed the impact of mobility models on the routing. They used PARSEC, which is a discrete-event simulation language to simulate AODV, DSR, and ZRP protocols. The simulation results exhibited that the topology and movement of the nodes are important factors in the performance of the network protocols. Oo et al. [8] compared AODV and AOMDV protocols by modeling mobility using Manhattan Grid model. The results indicate that routing load of AOMDV significantly reduces by maintaining multiple routes as the number of nodes increases. It is also found that the throughput of AOMDV is significantly higher. However its average delay and packet loss rate are not better than AODV. In [9] the authors studied the effect of the different mobile node movement pattern using AODV. The results are obtained using OMNET++ simulator. The authors found that the performance of the routing protocol varies across different performance metrics. Huang et al. [10] presented a simulation based comparison of energy consumption for DSR and AODV. The analysis considers the cost for sending and receiving traffic, for dropped packets, and for routing overhead packets. The observations indicate that energy spent on receiving and discarding packets has significant contribution. The results show that energy cost for AODV is higher as AODV generates broadcast packets more often.

Doshi et al. [11] proposed an extended version of the DSR protocol to improve energy efficiency. Firstly, a working path is identified with the help of a conventional route discovering circle. A node that is not on the path sends a message to the source if it considers itself as energy efficient. The source then identifies an energy efficient route by using this information. Gowrishankar et al. [12] studied the effects of various random mobility models on the performance of AODV. Three random mobility scenarios: Random Waypoint, Random Walk with Reflections and Random Walk with Wrapping have been considered for this purpose.

Senouci and Naimi [13] extended AODV and proposed three novel energy conserving schemes. The energy consumption of the overall network is reduced by controlling the transmission power using route cost metric. The passive route refreshing scheme and controlled broadcast is designed to balance the energy consumption. Domingo et al. [14] designed a simple energy-aware DSR protocol (SEADSR). The remaining energy levels of the nodes are considered in route discovery. The intermediate nodes avoid the RREQ messages if their energy level is under a threshold. SEADSR prefers the route that minimizes energy consumption. Wang et al. [15] adopted a power controlled mechanism to improved AODV and presented an energy saving routing protocol named ES-AODV. Authors claimed that ES-AODV improved the node lifetime and exhibited the energy saving performance as compared to the AODV protocol.

Tie-Yuan et al. [16] presented a comparative study on mobility models with the help of the NS-2 simulator. The effect of mobility on the performance routing protocols was analyzed by varying the speed and the pause time. Authors concluded that even setting the same parameters, different mobility model have different impact on the performance of the protocols.

III. BACKGROUND

This section briefly describes the AOMDV routing protocol and mobility models used in this work. The mobility model is designed to describe the movement pattern of mobile nodes. It includes change in their location, velocity and acceleration over the time.

A. *Ad hoc On Demand Multipath Distance Vector Routing Protocol*

AOMDV is based on widely used and well-studied on-demand single path routing protocol called AODV. AOMDV extends the AODV protocol to discover multiple paths between end nodes in every route discovery [6]. As in AODV, when a traffic source needs a route to a destination, the source initiates a route discovery process by generating a route request (RREQ) message. In AODV, only the first copy of the RREQ is used to form reverse paths. However, AOMDV examines all duplicate copies for potential alternate reverse paths. The reverse paths are formed only using those copies that preserve loop-free and disjoint paths. When the destination receives RREQ copies, it also forms reverse paths in the same way as intermediate nodes. However, it adopts a looser policy for generating a route reply (RREP) message in response to every RREQ copy that arrives via a loop-free and disjoint path.

Like AODV, AOMDV also uses route error (RERR) packets. A node generates or forwards a RERR for a destination when the last path to the destination breaks. AOMDV also includes an optimization to salvage packets forwarded over failed links by re-forwarding them over alternate paths. The timeout mechanism similarly extends from a single path to multiple paths. AOMDV follows the approach of using a path until it fails and then switch to an alternate path.

B. *Random Waypoint Mobility Model*

Johnson and Maltz [17] proposed a simple stochastic mobility model known as Random Waypoint (RWP). It is a benchmark mobility model widely used to evaluate the routing protocols because of its simplicity. In RWP, a node perpetually chooses destinations called as waypoints. After a constant pause time, the node moves towards a waypoint with a speed given in an interval. After arriving at that waypoint, it again waits for a pause time and then chooses the next waypoint. RWP and its variants are simple and easy to implement but they may not represent some realistic characteristics of mobility.

C. *Gauss-Markov Mobility Model*

The Gauss-Markov mobility model proposed by Liang and Haas [18] models the node velocity as a Gauss-Markov stochastic process by assuming it to be correlated over time. The initial position, velocity, and direction of nodes are uniformly distributed. The node movement varies after a time interval. The future values for velocity and direction are determined from the current values. This model is a temporally dependent mobility model. A memory level parameter α is used to determine degree of dependency. The parameter α reflects the randomness of Gauss-Markov process.

D. *Reference Point Group Mobility Model*

The Reference-Point-Group-Mobility model (RPGM) [19] uses reference points realizing spatial dependence to model the movement of group of nodes. The actual position of a node is determined by adding a random movement vector to the position of its reference point. The absolute position of a reference point can change arbitrarily over the time, but the relative positions of the reference points inside a group do not change. The velocities of different nodes are correlated and neighboring nodes can influence the velocity of the other nodes.

E. Manhattan Grid Mobility Model

Manhattan grid mobility model [20] restricts the movement of nodes to a geographical area by using information obtained from road maps. It emulates the movement pattern of nodes on streets in a city. Therefore it is very useful to model movement of nodes in an urban area. The area is divided into a number of horizontal and vertical streets. Nodes are modeled as pedestrians moving on the streets. Initially, all the nodes are randomly distributed over the map of the streets. Each node is given an initial velocity and direction. At an intersection of streets, the mobile node can go straight or turn left or right with certain probability. At the corners, the node can change direction with a certain probability. The velocity keeps changing over the times.

IV. METHODOLOGY

The performance of routing protocols can be evaluated either by deploying a real MANET or by simulation. The first approach involves a lot of cost. In the absence of real infrastructure, the real scenario can be studied by simulation. However it may lead to unsound results if unrealistic models are used. In this research work, the evaluation is done through extensive simulation carried out using Network Simulator-2 (NS-2) in its version 2.34. NS-2 is chosen partly because of its range of features and partly because of its widely acceptance.

The main goal of understanding energy consumption in the context of routing protocol requires a simulation environment that combines network and link layer tracing with wireless propagation and mobility models. In this work, a network area of 1000m×500m is created for node movement for 900 seconds of simulation time. The node movement is determined by different mobility models. For creating mobility scenario according to different mobility models another open source tool BonnMotion is used. Each node in the network waits for 10s and then moves towards destination at a speed of 20 m/s. The file containing node movements generated by BonnMotion tool are used as input to the NS-2. The number of nodes in the simulated MANET varies from 10 to 50 with an increment of 10 nodes. The constant bit rate (CBR) source is chosen to create a flow of traffic. The other simulation parameters are given in Table 1.

The simulation results obtained are analyzed in terms of energy consumed in transmission, energy consumed in receiving, energy consumed in idle mode, total energy consumption, and remaining energy. The transmission mode energy and receive mode energy are the energy consumed for transmitting and receiving data. In the idle mode, the interface has nothing to transmit and there is no data to receive too, but still it consumes some energy. This is default mode for ad hoc network environment.

Table 1: Simulation Parameters

Parameter	**Value**
Queue Length	50
Interface Queue	Drop Tail/Priori Queue
Traffic Type	CBR
Number of Connection	70% of the nodes
Packet Rate	8 packets/second
Pause Time	10 seconds
Speed of Nodes	20 m/s
Antenna	Omni directional
Simulation Area	1000m×500m
Number of Nodes	10, 20, 30, 40, 50
Initial Node Energy	1000 joules
Simulation Time	900 seconds

The performance metrics are described as follows.

- Transmission mode energy: This is the energy consumed by a node in transmitting data packets across the network. For the entire network, it is calculated by adding the energy consumption of individual nodes.
- Receive mode energy: The energy consumed by a node in receiving packets from other nodes in the network.
- Idle mode energy: The energy consumed while a node is doing nothing. A node needs some energy even when it is idle.
- Remaining energy: It is the energy left at the end of the simulation time. Larger remaining energy indicates longer network lifetime.
- Average energy: It is the average of the energy consumed in transmit, receive, and idle modes at all the nodes in the network.

The AOMDV routing protocol is simulated in NS-2 and the evaluation is done for all the above parameters.

V. Results and Discussion

The experiments are carried out according to the given methodology under varying conditions to evaluate the impact of mobility patterns on the consumption of energy during the network operations. Figure 1 shows the average energy consumption in transmission for the AOMDV protocol over RWP, RPGM, Gauss Markov (GM), and Manhattan (MH) Grid mobility models with varying number of nodes in the network. It can be observed that energy consumption increases sharply when node density increases from 10 to 20 nodes. It can be explained by the fact that when node density is low all the nodes are scattered far apart in the area and most of the nodes are not within the communication range of any other nodes. Due to sparse network, only few nodes are able to perform network operations resulting in only few transmissions of packets. As node density increases, sender-receiver pair increases and more nodes are able to communicate with other nodes. This increases packet transmission and thus increasing the energy consumption. When node density is increased further, the network load is shared between more nodes, thus reducing the average energy consumption at a node. It can be observed from the figure that Manhattan Grid mobility model is clearly the most expensive mobility model in this mode of operation. At node densities from 10 to 60 nodes, RPGM is the most efficient model. At higher node densities RWP outperforms the other mobility models.

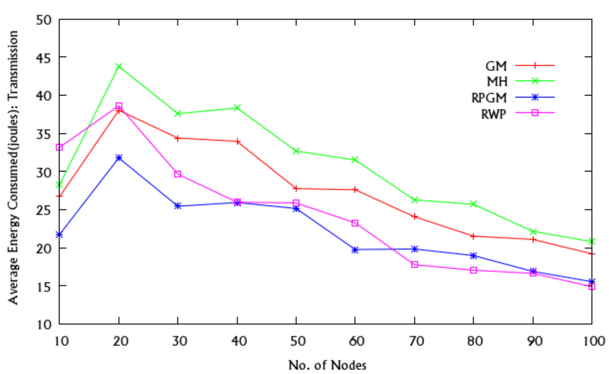

Figure 1: Average energy consumption in transmission mode

It is interesting to see from Figure 2 that Manhattan Grid mobility model which is most expensive in transmission mode, is the most optimal model in receive mode. Both RWP and RPGM which are better ones in transmission mode are little expensive in receive mode. The effect of node density is also different in this mode of operations. Energy consumption increases with the increase in the node density.

The pattern of energy consumption in idle mode as shown in Figure 3 is similar to that found in transmission mode. Energy consumption is decreasing with increasing node density. RPGM and RWP have shown the lower energy consumption but here RWP is the best one among the four mobility models considered and Manhattan Grid model is clearly the most expensive one.

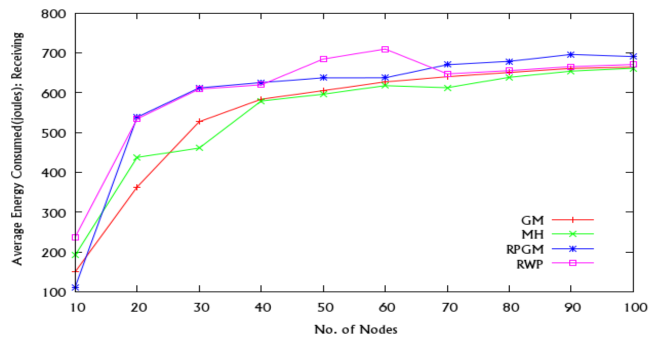

Figure 2: Average energy consumption in receive mode

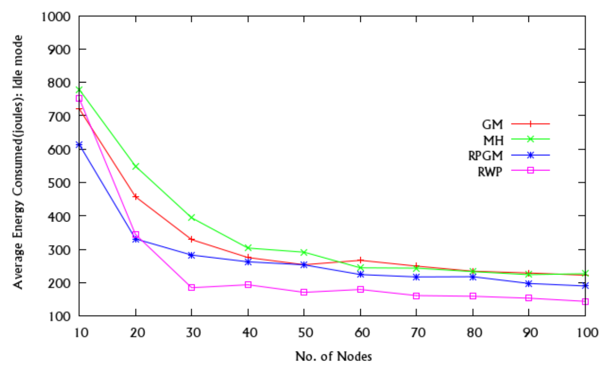

Figure 3: Average energy consumption in idle mode

Figure 4 summarizes the average energy left with the nodes at the end of the simulation. It can be observed that difference among the different mobility models is not very large but RWP model is clearly the better one. It means that in the simulated scenario nodes consumed least energy with RWP mobility models. Overall, it can be observed that mobility patterns have significant influence on the energy consumption in the network. Among the analyzed mobility models, the RWP generates pattern that better for the energy conservation in MANET operations.

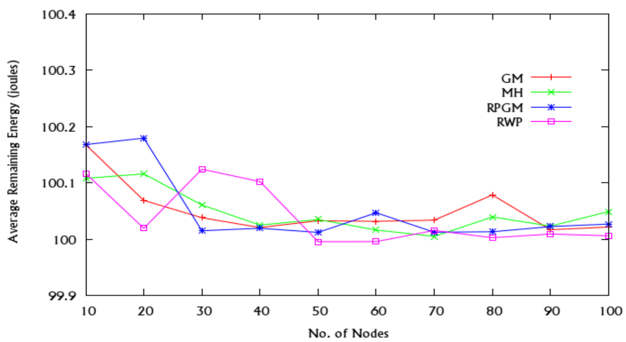

Figure 4: Average remaining energy

VI. Conclusion and Future Scope

In this work, the impact of mobility on the energy consumption for different network operations during routing in MANET was analyzed. The AODMV was used as candidate routing protocol in the experiments. The mobility patterns were generated using different mobility models including RWP, RPGM, Gaussian-Markov, and Manhattan grid. It can be concluded from the simulation results that mobility pattern influences the energy consumption in the network. Energy consumption lowest for patterns generated by RWP among all the considered mobility models. The future work includes development of an energy efficient routing protocols based on the results obtained.

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Author Profile

B. Kumar is MTech in Computer Science & Technology and PhD. He is working as Associate Professor in the Department of Computer Science & Information Technology at MJP Rohilkhand University, Bareilly. He is a member of IEEE. He has published several research papers in reputed international journals including Thomson Reuters (SCI & Web of Science) and conferences including ACM, IEEE, and Springer. His research interests include wireless networks, image processing, pattern recognition, and remote sensing.