VARIABLE RANGE ENERGY EFFICIENT LOCATION AIDED ROUTING FOR MANET

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ABSTRACT

A Mobile Ad-Hoc Network (MANET) is a temporary, infrastructure-less and distributed network having mobile nodes. MANET has limited resources like bandwidth and energy. Due to limited battery power nodes die out early and affect the network lifetime. To make network energy efficient, we have modified position based Location Aided Routing (LAR1) for energy conservation in MANET. The proposed protocol is known as Variable Range Energy aware Location Aided Routing (ELAR1-VAR). The proposed scheme controls the transmission power of a node according to the distance between the nodes. It also includes energy information on route request packet and selects the energy efficient path to route data packets. The comparative analysis of proposed scheme and LAR1 is done by using the QualNet simulator. ELAR1-VAR protocol improves the network lifetime by reducing energy consumption by 20% for dense and mobile network while maintaining the packet delivery ratio above 90%.

KEYWORDS

MANET, LAR1, Packet Delivery Ratio, Energy Consumption

1. INTRODUCTION

Wireless communication is one of the fastest growing fields in Telecommunication Industry. These systems, such as cellular, cordless phones, wireless local area networks (WLAN) have become an essential tool for people in today's life. Using these systems and the equipments like PDA, laptops, cell phones user can access all the required information whenever and wherever needed. All these systems need some fixed infrastructure. It takes time and potentially high cost to set up the necessary infrastructure. There are situations where user required networking connections are not available in a given geographic area, and providing the needed connectivity and network services in these situations becomes a real challenge. So, in this situation mobile communication network without a pre-exist network infrastructure is the best solution. The Ad Hoc Networks are wireless networks characterized by the absence of fixed infrastructures. The main aim of mobile ad- hoc network (MANET) [1] is to support robust and efficient operation in mobile wireless networks.

MANET consists of mobile nodes which form a spontaneous network without a need of fixed 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. Hence, it forms multi-hop network. The ad-hoc networks are finding more importance likely due to the features that they can be easily deployed as well as reconfigured. This allows the use of this kind of network in

D.C. Wyld, et al. (Eds): CCSEA 2011, CS & IT 02, pp. 321–333, 2011.

DOI: 10.5121/csit.2011.1229

special circumstances, such as disastrous events, the reduction or elimination of the wiring costs and the exchange of information among users independently from the environment. The applications for MANETs are ranging from large-scale, mobile, highly dynamic networks, to small, static networks that are constrained by power sources [2]. It can be used in military communication, commercial sectors like disaster management, emergency operations, wireless sensor networks, etc.

Deployment of ad-hoc network leads to many challenges such as limited battery power, limited bandwidth, multi hop routing, dynamic topology, security [1]. But, the major issue in MANET is energy consumption since nodes are usually mobile and battery-operated. Power failure of a mobile node affects its functionality thus the overall network lifetime. To prolong life time of the network, ad-hoc routing protocol should consider energy consumption. Efficient minimum energy routing schemes can greatly reduce energy consumption and extends the lifetime of the networks. Different routing protocols are designed for MANET such as AODV, DSR, OLSR, ZRP, and LAR, which meets some of challenges explained above. But, they do not consider the energy-efficient routing. Here, we are proposing a scheme which uses energy efficient routing to route the data. The modification is done in position based LAR1 protocol.

Rest of the paper is organized as: a Section II different routing approach for MANET is discussed. Section III gives the brief overview of LAR1 protocol. The energy efficient routing schemes are surveyed in Section IV. Section V discusses a proposed idea. Section VI gives the detail description of simulation model and performance metrics used for experimentation. Comparative analysis of proposed and original LAR1 protocols using QualNet simulator is given in section VII. Finally, Section VIII concludes the paper with future work in Section IX.

2. DIFFERENT ROUTING APPROACHES FOR MANET

Many routing protocols have been developed for MANET with features like distributed operation, creation of loop free paths, security, and QoS support. MANET routing protocol is a standard that controls how nodes select the short and optimized route to route packets between communicating devices in a MANET. Routing protocols in MANET are broadly classified into proactive (Table-driven) and reactive (On-demand) routing protocols. These are based on routing strategy in MANET. Depending upon the network structure, the routing protocols are categorized as flat routing; hierarchical routing and geographic position assisted routing [3].

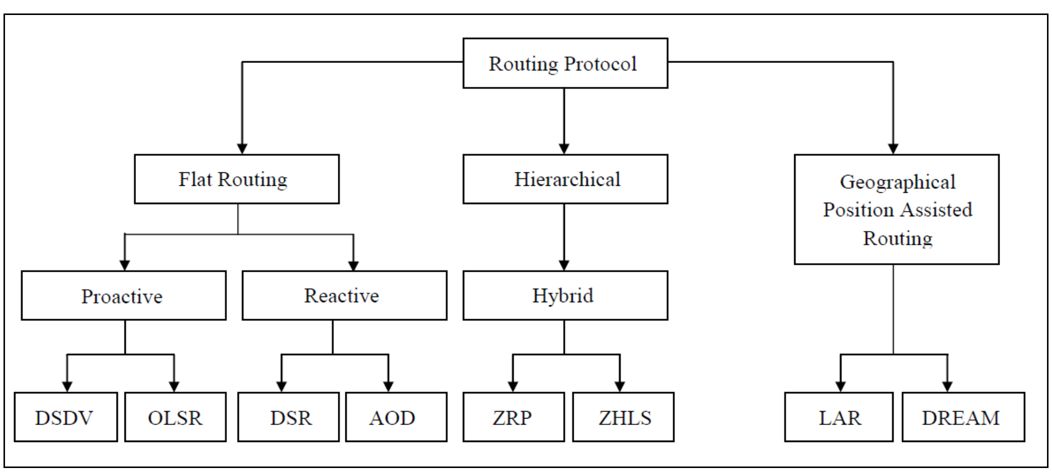

Figure 1. Classification of Routing Protocols

2.1. Proactive routing protocols

Proactive routing protocols maintain information in a table on each node about the routing to the other node in the network. Although the topology of the network does not change, this information must be updated periodically. Many proactive routing protocols have been proposed, for e.g. Destination Sequence Distance Vector (DSDV), Optimized Linked State Routing (OLSR) and so on.

2.2. Reactive protocols

These protocols don't maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet. The route discovery usually occurs by flooding the route request packets throughout the network. Several reactive protocols have been proposed such as Dynamic Source Routing protocol (DSR), Ad hoc On-demand Distance Vector (AODV), and so on.

2.3. Hybrid routing protocols

For larger networks, it is complex to design routing protocols. All nodes in the network are separated into groups, called cluster. All clusters form a hierarchical infrastructure. For such networks separate routing protocols have been designed which are known as hybrid routing protocols. These are the combination of proactive and reactive routing protocols. They are used in large networks in order to take advantages of proactive scheme for maintaining the routes in a cluster and reactive scheme for retaining the routes between the clusters. Several hybrid routing protocols have been proposed such as Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS).

2.4. Geographic position based Routing protocols

The above mentioned types of MANET routing protocols do not consider the geographical location of a destination node. Position-based routing protocols do not establish or maintain route, a packet is forwarded one hop closer to its final destination by comparing the location of destination with the location of the node currently holding the packet. These routing protocols make minimum use of the topology information, hence, they exhibit better scalability compared to topology-based routing protocols. Such protocols use 'localized' algorithms like greedy forwarding, in which a node forwards a packet to a next hop that is geographically closest to the destination among its one-hop neighbors. Several Position-based protocols have been proposed such as Location aided Routing (LAR) [4], Distance Routing Effect Algorithm for Mobility (DREAM), Most Forward within Distance R (MFR).

3. INTRODUCTION TO LAR1

Position-based routing protocols exhibit better scalability, performance and robustness against frequent topological changes. These routing protocols use the geographical location of nodes to make routing in networks. This will improve efficiency and performance of the network. The main aim of Position-based LAR1 described in [4] is to reduce the control overheads by the use of location information.

3.1. Location Information

LAR1 protocol requires the information about geographical location of the nodes in network. This location information can be determined by using Global Positioning System (GPS) [5]. By using location information, LAR1protocol limits the search for a new route to a smaller request zone of the ad hoc network. This results in a significant reduction in the number of routing messages.

3.2. Estimation of Expected and Request Zones

LAR1 has two types of zone, Expected zone and Request zone, to restrict the flooding of route request packets. A source node uses the location service to find out the location of the destination and according to that information it will set the expected zone. Request zone is also determined by the source node and it is zone where a route request should be forwarded from source.

3.2.1. Expected Zone

Expected zone is set up by the source node S when it has data intended for destination node D. By using location service node S estimates the geographical location of node D at time t_0. Suppose node D was at location O at time t_0, and that the current time is t_1. From this information node S is capable of determining the 'expected zone' of node D from the viewpoint of node S by time t_1. It is the region that node S expects to contain node D at time t_1. For instance, if node D is travelling with average speed ν, then node S assumes that node D is in the expected zone of circular region of radius $\nu (t_1 - t_0)$, centered at location O. The expected zone is only an estimate made by node S to determine a region that may contain D at time t_1. Since, if actual speed of node D is greater than the average, then the destination D may actually be outside the expected zone at time t_1. Figure 1 shows the expected zone created by the source node S.

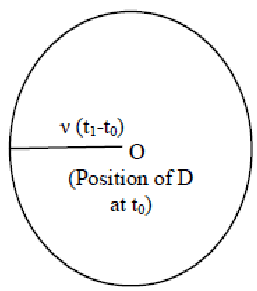

Figure 2. Expected Zone

3.2.2. Request Zone

The 'request zone' is different from the expected zone. It is the zone where a route request should be forwarded from source. An intermediate node will forward a route request packet only, if it belongs to the request zone. The request zone should contain the expected zone to reach destination node D. The source node S defines this zone for flooding the route request packets. An intermediate node will forward the request packet, only if it is located within the request zone.

3.3. Protocol Functioning

In LAR1 scheme the request zone is of a rectangular shape. Assumption is that the source node S knows the destination node D's average speed ν and location (X_d,Y_d) at time t_0. The request zone is considered to be the smallest rectangle that includes the current source location, and the expected zone. The sides of the rectangle are parallel to X and Y axes. The source node determines the request zone and initiates the route request packet containing the four corners coordinates of request zone. Each intermediate node, receiving the request packet, checks whether it belongs to the rectangle; if it does not, it will discard the packet such as node Q does in the following Figure 2. In the same Figure 2, node P will forward the packet because it belongs to the rectangle. In the reply packet, node D will attach its accurate location and the current time stamp, which will be stored in the source's cache for future use.

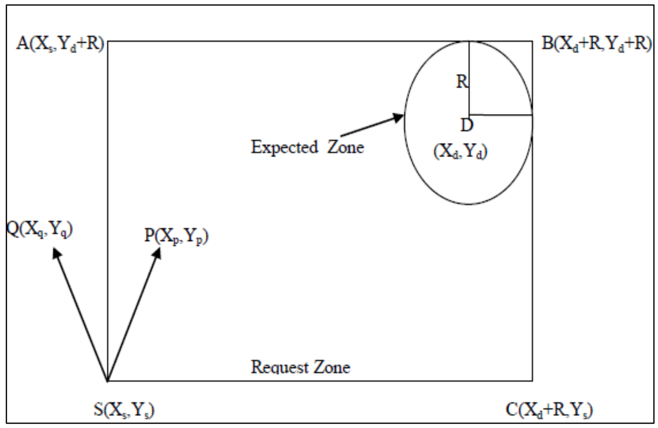

Figure 3. Working of LAR1

4. BRIEF OVERVIEW OF ENERGY EFFICIENT ROUTING SCHEMES

Several energy-efficient techniques are proposed to reduce energy consumption in MANET. These techniques use energy aware metrics to establish a path in a network. These metrics are residual energy, transmission power or link distance. Niranjan Kumar Ray and Ashok Kumar Turuk have discussed different energy efficient techniques for wireless ad-hoc network [6]. One of the techniques is based on reduction of number of route request messages. In second Power control technique, next hop node is chosen depending on the power level of the node. Topology control technique is used to remove the energy-inefficient link from the network by examining the power level of the node. This technique helps network devices to take decision about their transmission range.

Morteza Maleki, Karthik Dantu, and Massoud Pedram in [7] have proposed a new power-aware source-initiated (on demand) routing protocol for mobile Ad-hoc networks that increase the network lifetime up to 30%. A greedy policy was applied to fetched paths from the cache to make sure no path would be overused and also make sure that each selected path has minimum battery cost among all possible path between two nodes. Power-aware Source Routing (PSR) has taken care of both the node mobility and the node energy depletion that may cause a path to become invalid.

Energy-based Route Discovery Mechanism in Mobile Ad Hoc Networks [8] selects the route which has lowest energy cost in the network. The energy cost represents energy consumption of the network in order to prolong all connections between source and destination nodes. The energy cost is calculated using realistic energy consumption modeling which is used the channel quality to decide whether each packet is successfully received.

Location aided Energy-Efficient Routing protocol (LEER) protocol finds out the all possible paths from source to destination and selects minimum energy path to route the packets [9]. The selection of next hop node is based on whether it is situated near to destination than to source as well as transmit power of that node.

An energy aware routing scheme in location based ad-hoc network has proposed by Jangsu Lee, Seunghwan Yoo and Sungchun KimIn [10]. This method modifies the LAR protocol in which the virtual grid is applied to ad hoc network region and high energy node is selected as header for each grid which communicates information about nodes in that particular grid. The transmit power of nodes is adjusted according to the distance between them. The next hop node will be selected based on transmit power and its distance from the destination.

Nen-Chung Wang and Si-Ming Wang [11] have proposed a scheme which decides the baseline line between the source node and the destination node, for route discovery. The next hop is then selected based on baseline by broadcasting the request packets in request zone. The neighboring node with the shortest distance to the baseline is chosen as the next hop node. This method reduces control overheads by finding a better routing path than LAR scheme. They have proposed a partial reconstruction process for maintaining broken links of routing path.

Arthi Kothandaraman has proposed a protocol which based on transmission power control [12]. It varies the transmission range of a node to exclusively accommodate an independent node's neighbor set. This purely distributed as well as protocol independent scheme and preserves connectivity, and allows low power transmissions.

5. Proposed Scheme

LAR1 protocol uses location information of a node for setting the path from source to destination. We take this feature of LAR1 as a key factor in designing of variable range technique. The main aim is to design a technique of variable transmission power control to reduce overall energy consumption of the network. RREQ in LAR1 protocol consists of source location and destination location information. We have used this information to calculate the distance between the nodes. We also embed the energy factor of the node in RREQ packet for selection of energy efficient path.

5.1. Energy Factor Calculation

Yang Qin et. al. [13] have proposed an energy efficient routing metric called as Energy factor. They have used this metric for multipath concept where the most energy efficient as well as shortest path is selected to deliver the data packets. Similarly, in our method we use this metric to select the next hop node while discovering the path to destination. We define an energy-efficient routing metric for selecting the node having sufficient energy to route the packets. The terms used in metric are as follows:

EF_p: Energy Factor of node p

RE_p: Remaining Energy of node p

IE_p: Initial Energy of node p

Energy factor is calculated by using the formula (1) for every node when it receives route request or data packet.

$$EFp = REp \,/\, IEp \tag{1}$$

The EF of all the nodes along a valid path are multiplied together to obtain the EF of the path. We define it as minimum cost and it is given by-

$$Minimum\ cost = \prod_{p \in N} EFp \tag{2}$$

Where, N: Number of nodes between source S and Destination D.

Minimum cost metric selects the most energy-efficient path. The purpose of multiplication of EF values is to select the nodes having sufficient energy so that the minimum cost of the path from source to destination is high.

5.2. Algorithm for ELAR1-VAR

a) Firstly the initial transmission power is set at the physical layer of each node in the network, for a data rate of 2 Mbps. We have set 25 dBm transmit power as initial transmission power which sets initial transmission range 'Tr' for each node.

b) A source node S determines the location and velocity of destination node and sets the expected and request zones accordingly.

c) Source node S floods RREQ packets containing the coordinates of request zone and location information of S in the request zone.

d) Upon receiving RREQ packet at intermediate node, first it checks whether it is in request zone or not.

e) If intermediate node is in request zone then,

    i. It calculates EF of node itself and minimum cost of path to reach this node from source S.

    ii. Intermediate node within the request zone is selected if the minimum cost obtained is above threshold value otherwise node will not be selected as next hop node to forward the RREQ packets

    iii. After the selection of next hop node, node calculates its distance from previous node. If an intermediate node $I(X_i, Y_i)$ receives a RREQ packet from a node poisoned at $J(X_j,Y_j)$, then dist(i,j) is calculated using the Euclidian distance measurement in (3)

$$dist(i,j) = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2} \quad (3)$$

    iv. If dist(i,j) $<$ Tr, then according to the distance transmission power is set at the physical layer of node J.

f) If intermediate node is not in request zone then it simply discards the RREQ packet.

g) When destination node receives the RREQ packet, it generates RREP containing its location as well as velocity at current time instance and sends it to source node S.

6. Simulation Model and Performance Metrics

Simulator used for the comparative analysis is QualNet 5.0 [14]. It is suitable for designing new protocols, comparing different protocols and traffic evaluations. QualNet architecture is divided into three levels, Kernel, Model Libraries and Graphical User Interface (GUI). The user can use the QualNet GUI for creating and animating network scenarios, and analyzing their performance using the analyzer.

6.1. Simulation Model

Simulation model is comprised of traffic model, mobility model, energy model, and battery model. The detailed description of all these are as follows:

6.1.1. Traffic Model and Mobility Model

Traffic is generated using constant bit rate (CBR). The packet size is limited to 512 bytes. The mobility model is used to describe the movement pattern of mobile users, and how their location, velocity and acceleration change over time. Random waypoint mobility model is used to give mobility to nodes in the network.

6.1.2. Energy Model

Energy model is used to analyze the overall energy consumption of the network. QualNet supports generic energy model [15]. We have used generic energy model for experimentation because it can estimate energy consumption in transmitter for the case of continuous and variable transmit power levels. Table 1, shows specifications of generic energy model.

Table 1. Generic Energy Model

Parameter	**Values**
Power Amplifier Inefficiency factor	6.5
Transmit Circuitry power Consumption	100.0 mW
Receive Circuitry power Consumption	130.0 mW
Idle Circuitry power Consumption	120.0 mW
Sleep Circuitry power Consumption	0.0
Supply voltage (volt)	6.5

6.1.3. Battery Model

MANET consists of mobile nodes which are battery operated. QualNet has Linear Battery model which enables the analysis of the discharge behavior of the battery in mobile nodes.

6.2. Performance Metrics

Quality of a service is the performance level of a service offered by the network. The multimedia services demand for quick and better quality of data, it means the data rate and delay are the key factors for these services. For military applications, the security and reliable data delivery are of major concern. In sensor networks, the energy consumption and battery life would be the most important parameters. Different performance metrics are used for comparison are as given below-

6.2.1. Packet Delivery Ratio

It is the ratio of total number of data packets received successfully at destination to number of data packets generated at the source [16]. PDR values range from 0 to 1. Higher PDR values decide the consistency of the protocol.

6.2.2. End-to-End Delay

The end to end delay is the average time interval between the generation of a packet at a source node and the successfully delivery of the packet at the destination node [16]. Low end to end delay gives better performance of the network.

6.2.3. ECSDD (Energy Consumption per Successful Data Delivery)

It is the ratio of total energy consumption to the number of data packets successfully delivered to the destination [17]. Lower the ECSDD values indicate that node uses less energy for data communication. This helps in extending the lifetime of node and thus overall network lifetime.

6.2.4. Average energy consumption

Energy consumed by all nodes in the network [17]. Energy consumption should be as low as possible so as to make fair utilization of limited battery power.

7. SIMULATION RESULTS AND DISCUSSIONS

The network area taken for experimentation is 1000m x 1000m. The comparison of proposed and original protocol is done for different number of nodes, speeds and packet rates. Battery model is used at the node level with battery capacity 60mAHr .We have set the transmission power for nodes equal to 25 dBm. The scenario model for examining the ELAR1-VAR in dense and moderately mobile network is given in Table 2.

Table 2. Scenario Model

Parameters	Variation of Number of Nodes	Variation of Node speed	Variation of Packet rate
Area(m^2)	1000 x 1000	1000 x 1000	1000 x 1000
Nodes	20,40,60,80,100	50	50
Node Speed(m/s)	10	1,5,10,15,20,25,30	10
Simulation Time(s)	900	900	900
Pause Time(s)	100	100	100
Traffic Type	CBR	CBR	CBR
Traffic Load	50%	50%	50%
Packet Rate(packets/s)	4	4	2,4,6,8,10
Initial Power	60 mAHr	60 mAHr	60 mAHr

7.1. Impact of Variation of Number of Nodes

Simulation parameters for analysis of variation of number of nodes are given in Table 2. Both protocols are analyzed for variation of nodes from 20 to 100. This will help in analyzing the behavior of protocols in dense and sparse network.

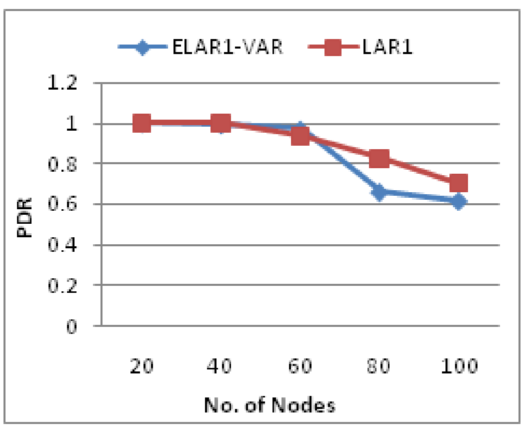

Figure 4. PDR vs. No. of Nodes

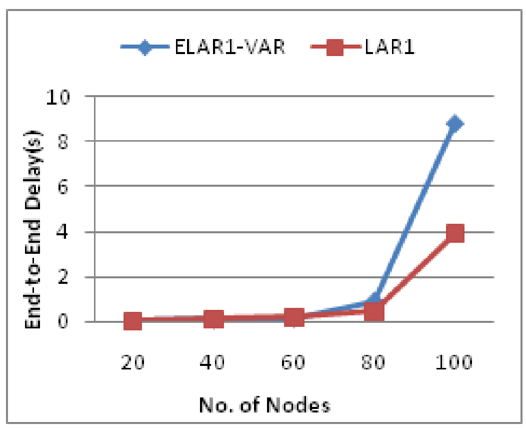

Figure 5. End-to-End Delay vs. No. of Nodes

The variation of PDR and end to end delay with respect to number of nodes is shown in Figure 4 and Figure 5 respectively. It is observed that ELAR1-VAR has same packet delivery as LAR1 up to 60 nodes. PDR for highly dense network is slightly less. We can say that ELAR1-VAR is suitable option for low as well as dense network. End to end delay for modified protocol is equal to original one but for highly dense network it increases rapidly. This is because the modified method calculates the distances between the nodes for setting transmit power which increases the processing time of RREQ at intermediate node.

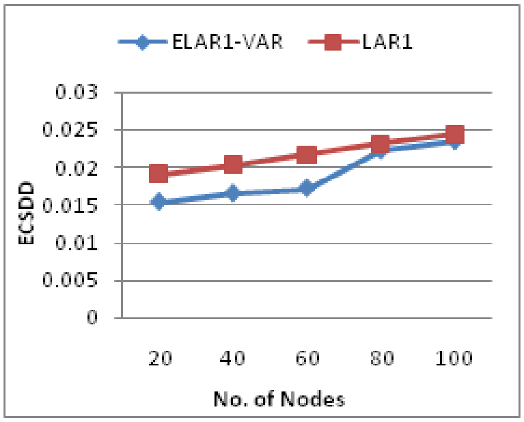

Figure 6. ECSDD vs. No. of Nodes

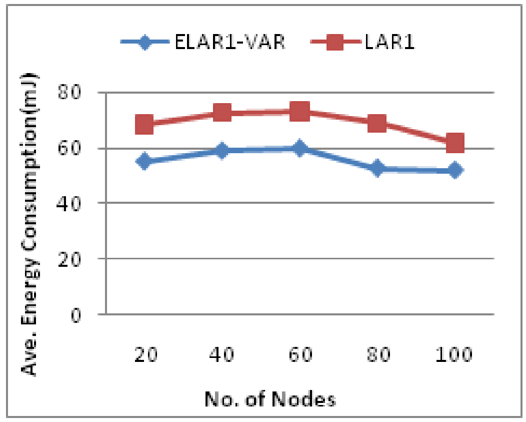

Figure 7. Ave. Energy Consumption vs. No. of Nodes

Figure 6 and Figure 7 shows ECSDD graph and energy consumed for different number of nodes respectively. The modified protocol consumes low energy for each successful data delivery. Hence, we can use ELAR1-VAR protocol for energy efficient applications. It is clear from figure 5 that energy consumption for ELAR1-VAR decreases approximately by 20%.

7.2. Impact of Variation of Node Speed

We are varying the speed of mobile nodes from 1m/s to 30 m/s to see the performance of ELAR1-VAR in mobile environment. The results for different performance metrics are as follows:

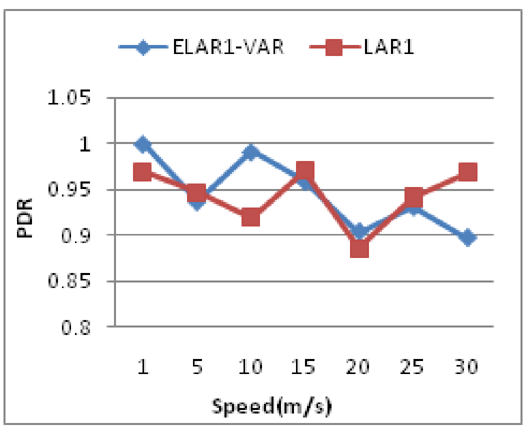

Figure 8. PDR vs. Speed

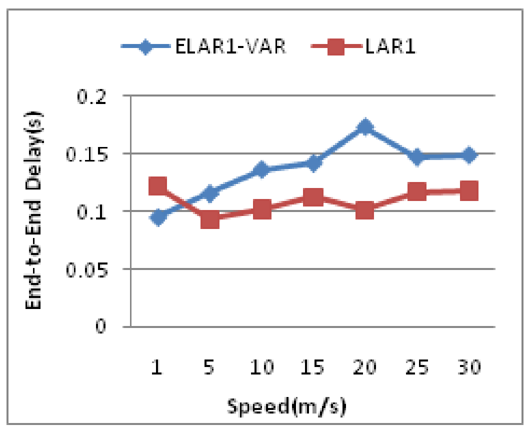

Figure 9. End-to-End Delay vs. Speed

The PDR and end to end delay results for different speeds are as shown in Figure 8 and Figure 9 respectively. If we increase the speed from 1 to 30 then PDR for ELAR1-VAR is approximately above 90% which indicates that it gives better results in low as well as high mobility network. There is an increase in delay for modified protocol. This is because location of node changes rapidly as node speed increases and node has to send new control packets which results in more delay.

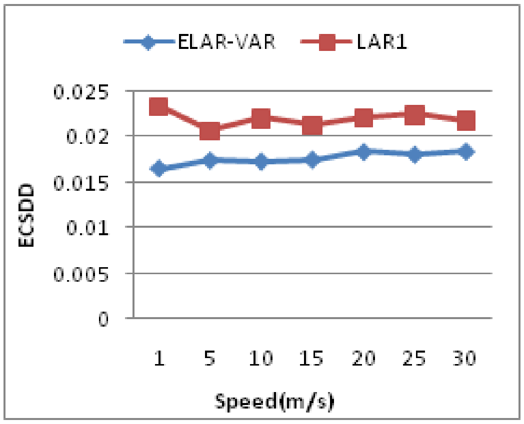

Figure 10. ECSDD vs. Speed

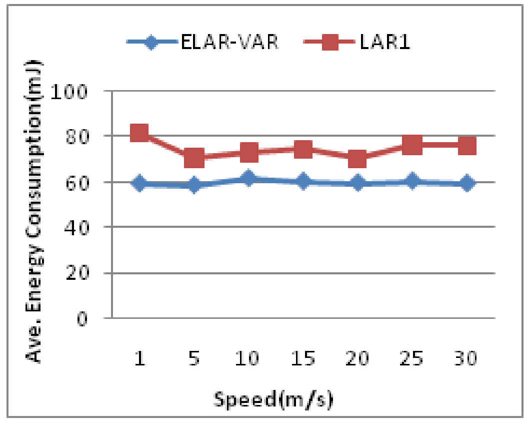

Figure 11. Average Energy Consumption vs. Speed

Impact of speed variation on ECSDD is shown in Figure 10. Energy consumption and ECSDD for ELAR1-VAR is less than LAR1. But, as speed increases the energy consumption in Figure 11 for both the protocol remains same. It is clear from Figure 10 that the energy consumption per data delivery decreases which improves the battery lifetime.

7.3. Impact of Variation of Packet Rate

Packet rate is varied from 2 to 10packets/second. Packet rate is varied to analyze the network capability of handling large number of data at a time.

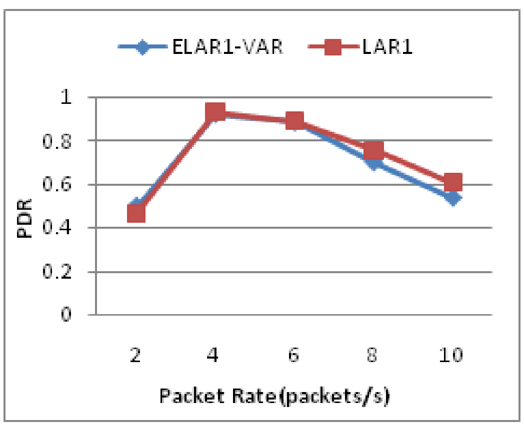

Figure 12. PDR vs. Packet Rate

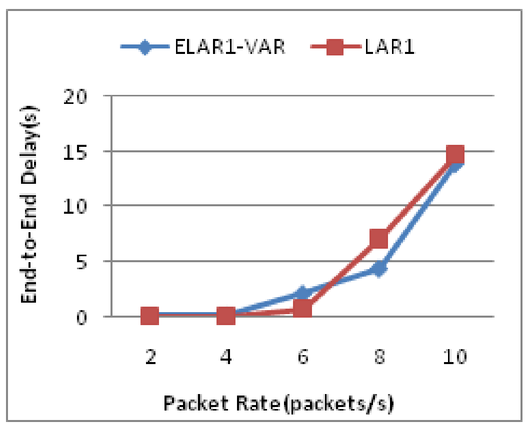

Figure 13. End-to-End Delay vs. Packet Rate

Figure 12 gives performance comparison of ELAR1-VAR with LAR1 in terms of PDR. There is increasing trend of PDR for both ELAR1-VAR and LAR1. As shown in Figure 13, ELAR1-VAR has comparable delay value for lower packet rates. Delay increases with the packet rate for both protocols. Since, the more packets are to be sent at a time which overflows the buffer resulting in dropping of packets. Hence, packets are to be retransmitted which increases the end to end delay.

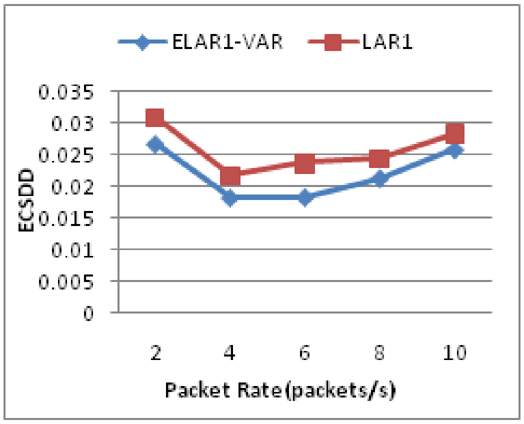

Figure 14. ECSDD vs. Packet Rate

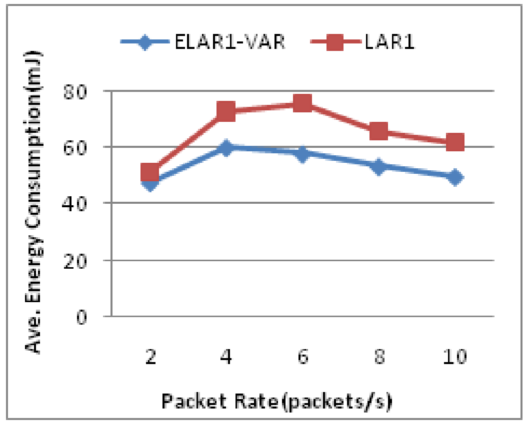

Figure 15. Average Energy Consumption vs. Packet Rate

As depicted in Figure 14, there is noteworthy change in ECSDD value for modified protocol. Also as shown in Figure 15, the overall energy consumption for network decreases with ELAR1-VAR.

8. CONCLUSION

We compared ELAR1-VAR and LAR1protocols considering the performance metrics such as packet delivery ratio, end to end delay, average energy consumption, and ECSDD. Several simulations have performed under different network conditions to analyze the performance of modified protocol with LAR1. The analysis of results showed that there is very slight change in packet delivery but remarkable change in energy consumption. Packet delivery is low for highly dense network whereas for all speed variation it maintains 90% of PDR. Average end to end delay is less sensitive to node speed. Lower packet rate has less impact on delay. Since, delay increases rapidly for higher packet rate and highly dense network.

The ELAR1-VAR consumes less energy for dense and moderately mobile network having packet rate of 4 packets/second. It is observed that overall energy consumption of the network is decreased by 20%. In ELAR1-VAR, the energy consumption per successful data delivery is lowered and thus nodes in the network can communicate with each other for longer period. Thus, our aim of extending network lifetime is achieved.

9. FUTURE WORK

The work can be extended to analyze the performance of ELAR1-VAR for different performance metrics such control overheads, jitter and throughput. The performance of ELAR1-VAR can be compared for different network areas and number of CBR connections.

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