International Journal of Computer Networking, Wireless and Mobile Communications (IJCNWMC)
ISSN(P): 2250-1568; ISSN(E): 2278-9448
Vol. 4, Issue 5, Oct 2014, 7- 20

LINK QUALITY BASED POWER EFFICIENT ROUTING PROTOCOL (LQ-PERP)

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ABSTRACT

Recent years have witnessed a growing interest in deploying infrastructure-less, self configurable, distributed networks such as Mobile AdHoc Networks (MANET) and Wireless Sensor Networks (WSN) for applications like emergency management and physical variables monitoring respectively. However, nodes in these networks are susceptible to high failure rate due to battery depletion, environmental changes and malicious destruction. Since each node operates with limited sources of power, energy efficiency is an important metric to be considered for designing communication schemes for MANET and WSN. Energy consumed by nodes in MANET or WSN can be reduced by optimizing the internode transmission power which is uniform even with dynamic routing protocols like AODV. However, the transmission power required for internode communication depends on the wireless link quality which inturn depends on various factors like received signal power, propagation path loss, fading, multi-user interference and topological changes. In this paper, link quality based power efficient routing protocol (LQ-PERP) is proposed which saves the battery power of nodes by optimizing the power during data transmission. The performance of the proposed algorithm is evaluated using QualNet network simulator by considering metrics like total energy consumed in nodes, throughput, packet delivery ratio, end-to-end delay and jitter.

KEYWORDS: MANET, WSN, Routing Protocols, AODV

INTRODUCTION

Mobile Adhoc Network (MANET) is infrastructure-less, self-organising and rapidly deployable wireless networks, highly suitable for applications like emergencies and natural disasters and military operations [1, 2]. In MANET, each node communicates with other nodes directly or through intermediate nodes [3]. Thus, all nodes in a MANET basically function as mobile routers participating in deciding and maintaining the routes based on a routing protocol. Routing in MANETs is one of the key issues due to their highly dynamic and distributed nature. Further, as mobile nodes are powered by batteries with limited capacity, energy efficiency is one of the most important criteria for designing routing protocols. Power failure in a mobile node affects the ability to forward packets thus reducing the overall network lifetime. For this reason, many research efforts have been devoted for developing energy aware routing protocols.

A mobile node consumes its battery energy not only when it actively sends or receives packets but also when it stays idle listening to the wireless medium for any possible communication requests from other nodes.

Thus, energy efficient routing protocols can minimize either the active communication energy required to transmit and receive data packets or the energy consumed during inactive periods. In some protocols each node can save the inactivity energy by switching its mode of operation into sleep/power-down or simply turning radio off when there is no data to transmit or receive. This leads to considerable energy savings, especially when the network environment is characterized with low duty cycle of communication activities. However, it requires well-designed routing protocol to guarantee data delivery even if most of the nodes sleep and do not forward packets for other nodes. Another important approach for optimizing active communication energy is load distribution approach. The main goal of the load distribution method is to balance the energy usage among the nodes and maximize the network lifetime by avoiding over-utilized nodes when selecting a routing path. In other protocols, the active communication energy can be reduced by optimizing the transmission power required to deliver data packets to the destination. In this paper a link quality based power efficient routing protocol is proposed to address the power demands of MANETs. The remaining sections of the paper is organized as: related work is discussed in section 2. Proposed protocol is discussed in detail with algorithm used and flowchart in section 3. Simulation setup and results are discussed in section 4 followed by conclusions in section 5.

RELATED WORK

IEEE 802.11 [2] takes advantage of switching off the transceiver as a means to conserve energy. It employs two power saving modes, doze (sleep) mode and an awake (full power) mode. The standard describes two scenarios for power conservation. The first scenario addresses mobile nodes connected in an infrastructure type of network. The second scenario addresses an AdHoc network where no access point is present.

Another solution in minimizing power consumption at the PHY layer is to turn off the transmit/receive radio when the node does not anticipate any communication with other nodes. This technique is mentioned by Raghavendra and Singh [4]. Sivalingam et. al. [5] propose a reservation based scheduling approach in which nodes broadcast their transmission time schedules so that they can go into standby mode and switch back to active mode when their transmit time arrives. The Energy Conserving Medium Access Control (EC-MAC) protocol [5] was developed with an energy conservation goal in mind. It was developed for an infrastructure based wireless network where a single workstation serves mobile nodes within its coverage area. The authors argue that this protocol can be extended to an AdHoc network by allowing the mobiles to elect a coordinator to perform the base station functions. El Gamal et. al. [6] use an algorithm, Move Right, to solve a convex problem based on the idea that, in many channel coding schemes, lowering transmission power and increasing the duration of transmission leads to a significant reduction in transmission energy. The Power Aware Multi-Access (PAMAS) protocol modifies the Multiple Access with Collision Avoidance protocol (MACA) described by Karn [7]. As stated by Rao et. al. [8], error control schemes such as automatic repeat request (ARQ) and forward error correction (FEC) waste network bandwidth and consume energy.

Agrawal et. al. [9] study the effect of dynamic power control and forward error correction on power consumption. In their study, each node determines the minimal power and forward error correction required that satisfy a quality of service (QOS) constraint. Singh et. al. [10] use power-aware metrics for route discovery in addition to using PAMAS as a MAC protocol for their study. They report an energy improvement of 40 percent to 70 percent. Banerjee and Misra [11] developed a transmission power adaptive algorithm that finds the minimum energy routing path. The authors also use analytical methods to find the optimum transmission energy on each individual path in a multi-hop wireless network. Spyropoulos and Raghavendra [12] propose an energy-efficient routing and scheduling algorithm for use in nodes equipped with directional antennas. Krishnan et.al [13] have designed and implemented a protocol that selectively chooses short periods of time to suspend communication and shut down the transceiver. The algorithm handles the queuing and management of packets during this period.

Recently, a number of distributed schemes for efficient power management in sensor networks have also been proposed [5, 11, 14, 15, 16] that typically work well for very specific scenarios but lack more general theoretical support for their performance. Various clustering based routings in many contexts have been proposed in [17, 18]. A typical clustering scheme called low-energy adaptive clustering hierarchy (LEACH) uses the technique of randomly rotating the role of a cluster head among all the nodes in the network. In Power Efficient Gathering in the Sensor Information Systems (PEGASIS) [10], nodes are organized into a chain using a greedy algorithm so that each node transmits to and receives from one of its neighbors. A randomly selected node from the chain will forward the aggregated data to the base station, thereby reducing per round energy expenditure compared to LEACH. A clustering based routing protocol called Base Station Controlled Dynamic Clustering Protocol (BCDCP) [19], which utilizes a high energy base station to set up cluster heads and perform other energy-intensive tasks, can noticeably enhance the lifetime of a network. Lahriri et. al. [20] describe a new battery driven system level power management scheme, communication based power management (CBPM), that aims to improve battery efficiency. A comparison of power saving techniques at the MAC layer in IEEE 802.11 and ETSI HIPERLAN is presented by Woesner et. al. [3].

ROUTING PROTOCOLS

Mobile Adhoc Network [21] is a collection of wireless mobile nodes forming a temporary communication network without the aid of any established infrastructure or centralized administration. The lifetime of a MANET depends on the battery resources of the mobile nodes. So energy consumption becomes one of the important design criterions for MANET.

Routing is the process of moving information across an inter-network from a source to a destination. Along the way, at least one intermediate node typically is encountered. Routing is also referred to as the process of choosing a path over which to send the data packets. Routing protocols use metrics to evaluate what path will be the best for a packet to travel. A metric is a standard of measurement such as path bandwidth, reliability, delay, current load on that path etc. Metric is used by routing algorithms to determine the optimal path to a destination.

The purpose of the routing algorithm is to make decisions concerning the best paths for data. Routing algorithms guide and shape the way in which data is to travel from one network to the other. Routing protocols can also be classified as link state protocols [21] or distance-vector protocols [16]. Nodes using a link state routing protocol maintain a full or partial copy of the network topology and costs for all known links. Nodes using a distance-vector protocol keep only information about next hops to adjacent neighbours and costs for paths to all known destinations. Generally speaking, link state routing protocols are more reliable, easier to debug and less bandwidth-intensive than distance-vector protocols. Link state protocols are also more complex and more compute and memory-intensive.

LINK QUALITY-BASED POWER EFFICIENT ROUTING PROTOCOL (LQ-PERP)

LQ-PERP is a power efficient reactive routing protocol which considers link quality between the nodes of the active route to set the transmission power during data transfer to reduce the total energy consumption of each node and enhance its lifetime. Link quality based optimization of transmission power is based on Look Up Table (Table 1) which is prepared as explained in section 5.1 and stored in each node. If the source needs to send data packet to the destination, it searches for the route in an on-demand manner. The source node initiates a route discovery process by flooding RREQ message to all its neighbours which are in its radio range. The neighbouring node after receiving the RREQ message forward the request to its neighbours by flooding new RREQ message.

This process of forwarding RREQ message continues until it reaches the destination node. At the destination, RREP message is generated and is unicasted towards the source node through active intermediate nodes to establish route. During the process of route reply, node (including source) in the active route calculates the Link Quality Indicator (LQI) using equation1 upon receiving the RREP message. Based on the LQI value calculated in each node, optimum power to be set during data transmission is chosen from Look Up Table (table1 which is stored in each node) and stored in a node specific power variable.

$$LQI = \frac{\text{Received Message Power (mW)}}{[\text{Intreference Power (mW)} + \text{Noise Power (mW)}]} \quad (1)$$

Where, Received Message Power is the value of signal strength received for the corresponding RREP message. Interference power is the value of interference of the original signal with other signals on the same radio and noise power is a value of noise in that environment.

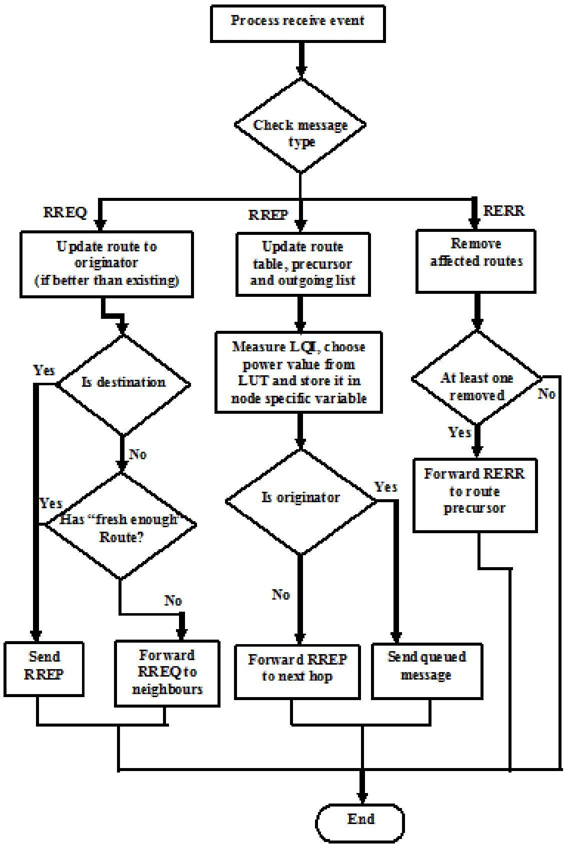

Figure 1(a): Flowchart for the Proposed Protocol to Handle Various Message Types

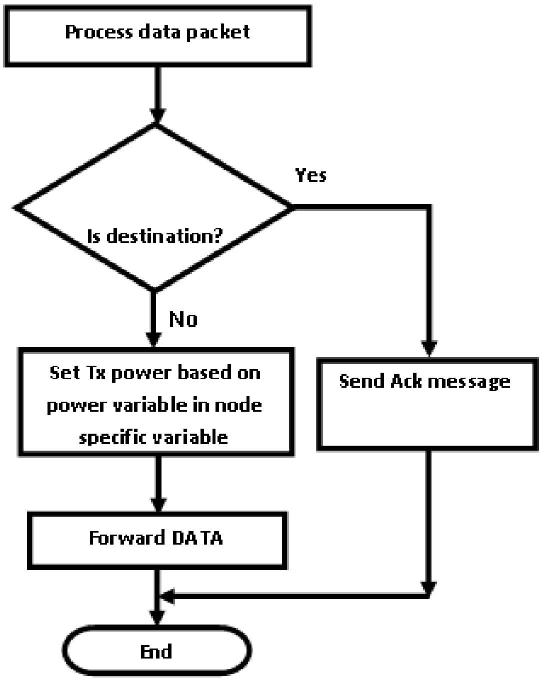

Figure 1(b): Flowchart for the Proposed Protocol to Handle Data Packets

Table 1: Transmission Power to Be Set for Range of LQI Values

LQI Range	Distance (m)	Tx Power Set
0-39	500	21dBm
40-60	450	19.9dBm
61-104	400	17.8dBm
105-204	350	15.6dBm
205-424	300	12.8dBm
425-789	250	9.7dBm
790-1399	200	6.8dBm
1400-3200	150	4.4dBm
>3200	100	0.8 dBm

As the path for data transmission is established between source and destination, the source node sets the transmission power to the power variable value stored in the node and transmits the data to next hop along the established route. Similar procedure is also followed by all other intermediate nodes along the established route to set the transmission power. The flowchart of proposed algorithm is shown in the figures 1(a) & 1(b).

SIMULATION AND RESULTS

Scenario -1

To establish the relationship between inter node distance, LQI value and optimum transmission power, a series of simulation studies have been carried out by varying transmission power and inter node distance considering PDR as performance metric. Initially, IEEE 802.11b scenario with two nodes placed 500m apart has been considered for simulation using Qualnet 5.2 simulator. Simulation studies have been carried out by varying transmission power and measuring corresponding LQI & PDR values (table 2). The variation of LQI and PDR as a function of transmission power is shown in figure 2.

Table 2: Transmitted Power, LQI and PDR Values for 500m

Power (dBm)	LQI	PDR (%)
19	16.35	0.01
19.5	18.35	0.091
20	20.59	0.54
20.25	21.81	0.7575
20.5	23.1	0.8989
20.75	24.47	0.9596
20.8	24.75	0.9697
20.85	25	0.989
20.9	25.33	0.989
21	25.92	0.99
21.1	26.52	0.99
21.2	27.1437	0.99
21.3	28.42	0.99
21.4	28.42	1
21.5	29.08	1
22	32.63	1

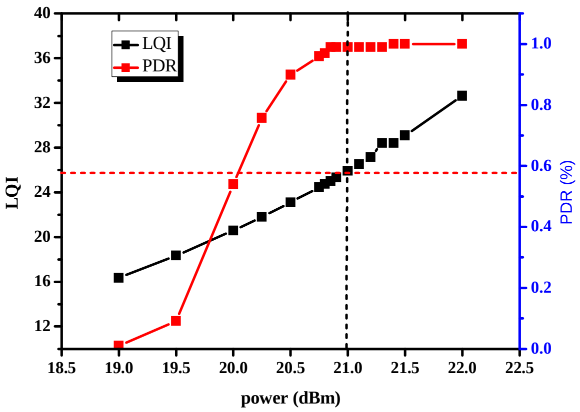

Figure 2: Variation of LQI and PDR as a Function of Transmission Power

The transmission power at which PDR attains a saturation value is referred as threshold power (P_{th}) and the corresponding LQI value is threshold LQI (LQI_{th}). The LQI_{th} is the minimum LQI value required to achieve PDR value almost equal to 1. From figure 2 and table 2 it is evident that, if the nodes are kept apart by 500m the threshold power is **P_{th}=21dBm** and corresponding **LQI_{th}=25.92**. Further, simulation studies have been repeated by reducing inter node distance upto 100m in steps of 50m and corresponding P_{th} values are measured (table 3). From these simulation studies it is also observed that, value of LQI_{th} is almost same and independent of distance between the nodes.

Simulation studies are repeated by setting transmission power at P_{th} for 500m (**21dBm)** and distance between nodes is decreased from 500m up to 100m in steps of 50m and corresponding LQI values are recorded (table 4). Using the information from table 3 and 4, distance and corresponding optimum power required for data transmission is estimated from the range of LQI values as listed in table 1.

Table 3: P_{th} with Inter Node Distance

Distance (m)	Tx Power Set
500	21dBm
450	19.9dBm
400	17.8dBm
350	15.6dBm

Table 3: Contd.,

300	12.8dBm
250	9.7dBm
200	6.8dBm
150	4.4dBm
100	0.8dBm

Table 4: Distance and LQI Values with P_{th}=21dbm

Distance (m)	LQI Range
500	25
450	40
400	62
350	105
300	205
250	425
200	790
150	1400
100	3200

Scenario-2

The Qualnet 5.2 simulator has been used to evaluate the performance of proposed routing protocol LQ-PERP and standard AODV protocol for IEEE 802.11b standard. The simulations are carried out for network sizes of 50,100,150,200,250 stationary and nodes with random way point mobility of 10mps. Simulations are configured with the parameters as shown in the table 5. The performance of the proposed protocol is compared with standard AODV protocol with respect to metrics like total energy consumed by all the active nodes in the routing path, throughput, total bytes received, PDR, delay and jitter. Figure 3 shows the snapshot of Qualnet simulator for 250 nodes with mobility of 10mps.

Table 5: Simulation Parameters

Radio Type	IEEE 802.11b
Routing Protocols	LQ-PERP and AODV
No. of Channels	One
Channel frequency	2.4 GHz
Path loss model	Two Ray
Energy model	Mica Motes
Shadowing model	Constant
Simulation time	300 second
Battery model	Linear model
Number of nodes	50,100,150,200,250
Traffic types	CBR
Mobility of nodes	None
	10mps Random Way Point
Node Placement	Random
Packet size	512 bytes

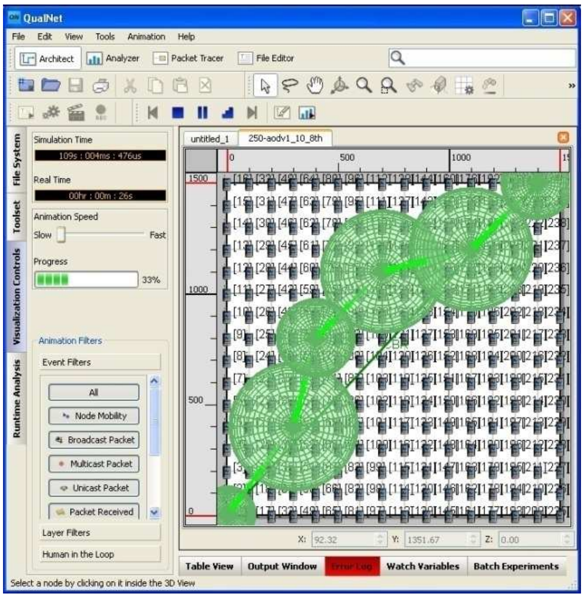

Figure 3: Snapshot of Qualnet 5.2 Simulator for 250 Nodes with Mobility of 10mps

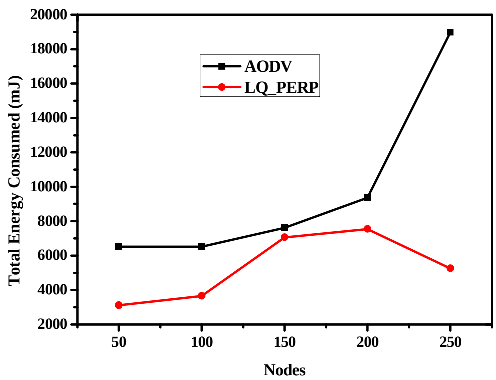

Figure 4 (a): Energy Consumed for Stationary Nodes Scenario

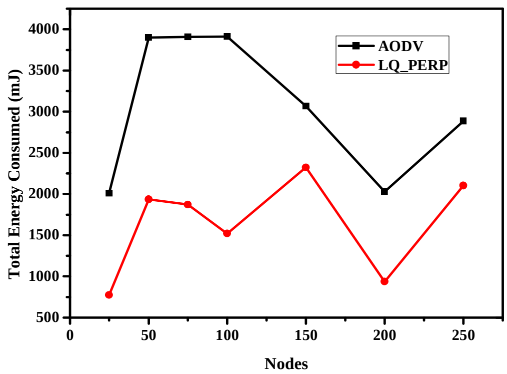

Figure 4 (b): Energy Consumed for Mobile Nodes

The variation of total energy consumed by all the active nodes in the routing path for the LQ-PERP and AODV protocols with different node density for stationary nodes is shown in figure 4(a) and nodes with mobility is shown in figure 4(b).

It is evident from figure 4(a) and 4(b) that, the energy consumed by the active nodes in the route for the proposed LQ-PERP protocol is considerably reduced compared to AODV protocol for both stationary and mobile nodes.

The observed reduction in power consumption by LQ-PERP protocol as compared to AODV protocol is due to optimization of transmitted power based on LQI value of channel between two active nodes of the route i.e., for channel with better LQI value data transmission can be achieved with reduced transmission power.

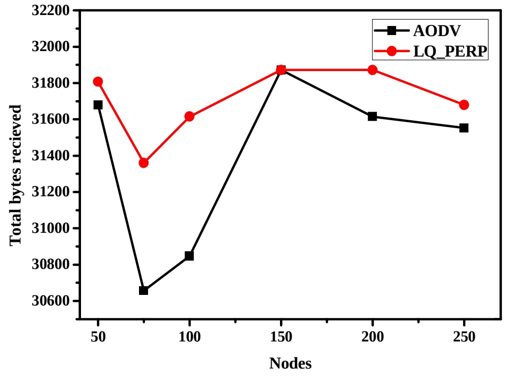

Figure 5 (a): Total Bytes Received for Stationary Nodes

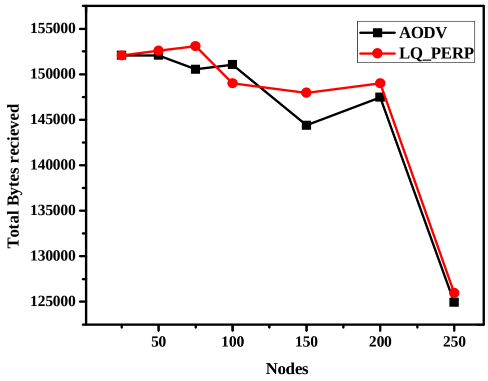

Figure 5 (b): Total Bytes Received for Mobile Nodes

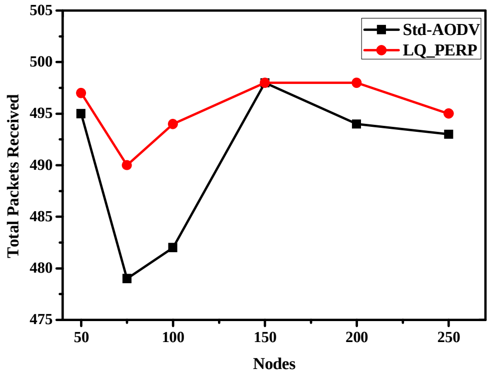

Figure 6 (a): Total Packets Received for Stationary Nodes

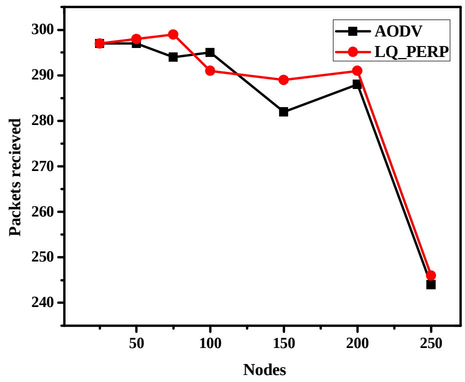

Figure 6 (b): Total Packets Received for Mobile Nodes

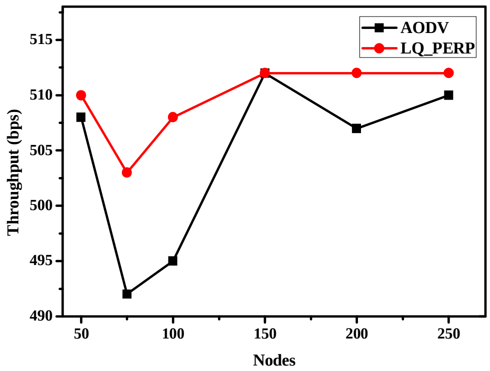

Figure 7 (a): Throughput for Stationary Nodes

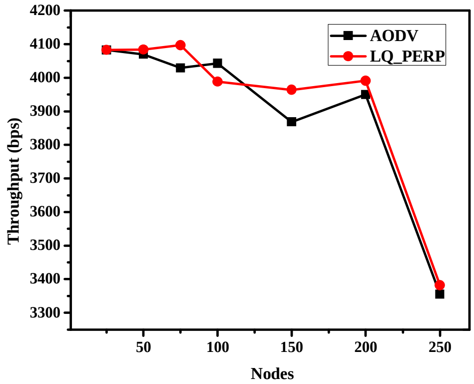

Figure 7 (b): Throughput for Mobile Nodes

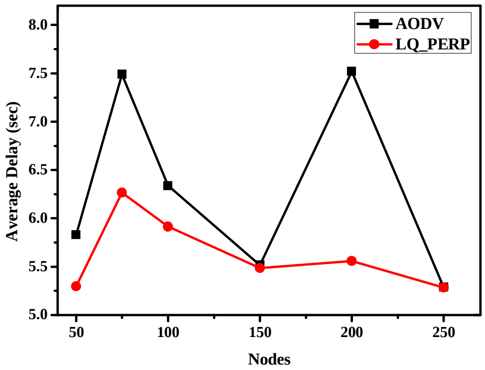

Figure 8 (a): End-To-End Delay for Stationary Nodes

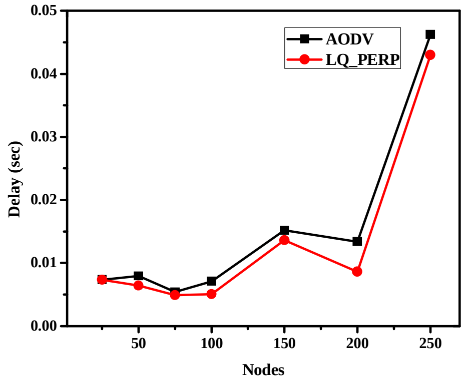

Figure 8 (b): End-To-End Delay for Mobile Nodes

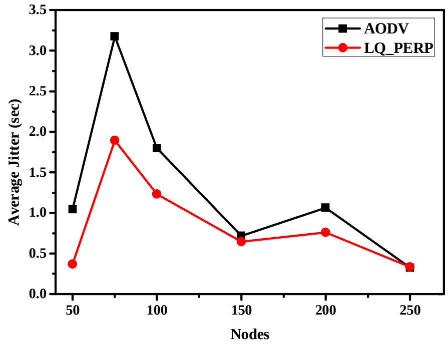

Figure 9 (a): Average Jitter for Stationary Nodes

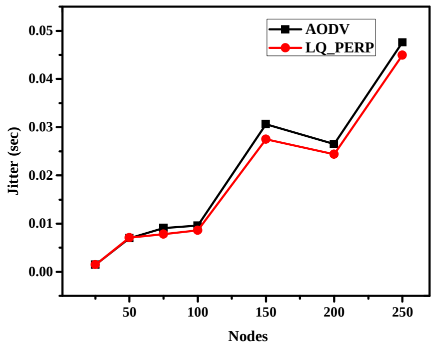

Figure 9 (b): Average Jitter for Mobile Nodes

Figures 5 (a, b), 6 (a, b), 7 (a, b), 8 (a, b) and 9 (a, b) depicts the variation of total bytes received, total packets received, throughput, end-to-end delay and average jitter for the proposed LQ-PERP and AODV protocols for stationary nodes and mobile nodes respectively. From the figures 5 to 9, it is evident that for stationary and mobile nodes the variation of total bytes received, total packets received, throughput, end-to-end delay and average jitter performance of the proposed LQ-PERP protocol is almost same and better as compared to AODV even though the transmission power is optimized. With this it is evident that proposed protocol increases the life time of the node/network by consuming less battery power without affecting the performance of the network.

CONCLUSIONS

In this paper, link quality based power efficient routing protocol (LQ-PERP) is proposed. The formulation of algorithm and implementation of the proposed protocol is discussed thoroughly. Using simulation studies the performance of the proposed protocol is studied for different node density with stationary and mobility scenarios. From the performance study, it is evident that the proposed protocol outperforms the standard AODV protocol with respect to total power consumed and in turn improves the life time of the network.

ACKNOWLEDGEMENTS

The authors would like to thank UGC for sanctioning the funds under major research project. One of the authors thank the management of BHS Higher Education Society. Authors would also thank Nihon communication, Bangalore for their support. Authors are greatful to University Grants Commission New Delhi for providing financial assistance to carry out this research work.

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