IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 1, January 2014)

Performance Study of Adhoc on-Demand Link Quality Aware Route Search Protocol (AO-LQARSP)

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***Abstract*— A Wireless Sensor Network (WSN) is a network with few tens to thousands of small devices called sensor nodes which are connected wirelessly and involve in communicating the data. WSNs have generated tremendous interest among researchers in recent years because of its potential usage in wide variety of applications. The sensor nodes in WSNs have scarce power; they work in harsh and unattended environments which initiates the need for a better and more reliable routing path to send data. In this paper a routing protocol is proposed to select the route based on better signal strength conditions using Link Quality Indicator of the received signal for IEEE 802.15.4 standard. The performance of the proposed routing protocol is compared with standard reactive routing protocol Adhoc On-demand Distance Vector (AODV) with metrics like total packets received, throughput, total bytes received, average end-to-end delay and average jitter and total energy consumed for various node density scenarios.**

***Keywords*— WSN, LQI, AODV, RREQ, RREP.**

I. INTRODUCTION

Wireless Sensor and Actuator Networks (WSANs) constitute an important and exciting new technology with great potential for improving many current applications as well as creating new revolutionary systems in areas such as Wireless sensor networks (WSNs). WSNs will potentially affect all aspects of our lives, bringing substantial improvements in a broad spectrum of modern technologies ranging from battlefield surveillance, environmental monitoring, biological detection, smart spaces, disaster search and rescue, industrial diagnostics, sensing a building integrity or structural vibrations during an earthquake, the stress of an airplane's wings, are some of the applications where WSN promise to change how researchers gather data [1].

Today, many sensors exist around the world collecting environmental data. In most cases, the WSN systems measure a limited number of parameters at a large granularity. WSNs have the potential of dense and flexible coverage and most importantly enabling correlation across many WSNs.

Dense coverage might include sensors placed within centimeters to meters distance between each of them, enabling a precise understanding of certain phenomena. A single sensor node may only be equipped with limited computation and communication capabilities. However, nodes in a WSN, when properly programmed and networked, can collaboratively perform signal processing tasks to obtain information of a remote and probably dangerous area in an untended and robust way [1,2].

In WSNs, since messages travel multiple hops it is important to have a high reliability on each link, otherwise the probability of a message transiting the entire network would be unacceptably low. Significant work is being done to identify reliable links using metrics such as received signal strength indicator (RSSI), link quality indicator (LQI) and packet delivery ratio. Routing is complicated if either the message source or destination or both are moving. Many protocols have been developed that rely on metrics to represent the reliability and integrity of the links [3-5]. The Packet Reception Rate (PRR) and Packet Loss Rate (PLR) are the most common of such indicators. Both PRR and PLR are based on a given number of packet transmissions. One of the most desirable features for LQI is its ability to use the minimum possible resources (time and energy) to assess the channel by high degree reliability. Evaluating the quality of a link in the shortest possible time allows algorithms to adapt rapidly to fast changes in the overall link quality configuration of a network. Link quality assessments made by spending the minimum possible energy are always desirable, especially working with energy-constrained sensor nodes. Examples of such indicators include the classical RSSI and the CC2420-specific LQI [6].

In this paper a link quality aware route search protocol is proposed to select stable routing path (with better received signal strength). The performance of the proposed protocol is compared with the standard Adhoc On-demand Distance Vector (AODV) routing protocol for various node density scenarios.

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II. Related Work

Most of the works that have been carried out are based on AODV (Adhoc On-demand Distance Vector) protocol [7], which was originally proposed in RFC 3965. LABILE (Link Quality-Based Lexical Routing) [8] proposes a routing algorithm based on lexical structures and link quality evaluation. Through the use of LQI, i.e., a metric provided by the physical layer of IEEE 802.15.4 standard [9], LABILE is able to evaluate the link quality. The LABILE proposal evaluates end-to-end link quality, by classifying the possible values of LQI into good or bad.

The EEURP (Energy Efficient Unicast Routing Protocol) [10] proposes a cost function to select routes based on hop count, the average energy consumption in the end-to-end path and the minimum energy level. A routing protocol based on three possible routing techniques is presented in [11]. The routing schemes are the following: simple routing, Round-Robin and weighted-Round Robin.

A number of wireless routing protocols are proposed to provide communication in wireless environment using open source simulators. Some among them are PAODV, AODV, CBRP, DSR and DSDV [12], performance of DSDV, DSR, AODV and TORA [13], performance of SPF, EXBF, DSDV, TORA, DSR and AODV [14], comparison of DSR and AODV [15], performance of STAR, AODV and DSR [16], comparison of AMRoute, ODMRP, AMRIS and CAMP [17], performance of DSR, CBT and AODV [18], comparison of DSDV, OLSR and AODV [19] and many more. These performance comparisons are carried out for ad-hoc networks.

There are several other efforts related to the work under study. In the work of Perkins et.al [20], evaluation of DSR and AODV was studied using nS-2 network simulator. Another relative work has been presented by Broch et.al [21]. In the work [22], four ad-hoc routing protocols are evaluated using nS-2 for 50-node network models. Besides comparison of adhoc networks several other papers have dealt with ZRP and worked on the perfect zone radius value. Hass and Pearlman have done extensive research in ZRP [23]. In [24] DSR and AODV is evaluated using NS-2 network simulator. Various routing protocols are been analysed in [25] including AODV and DSR.

III. Overview Of Routing Protocols

A WSN is a network consisting of numerous sensor nodes with sensing, wireless communication and computing capabilities.

These sensor nodes are scattered in an unattended environment (i.e. sensing field) to sense the physical world. The sensor nodes either form a flat network topology where sensor nodes also act as routers and transfer data to a sink through multi-hop routing, or a hierarchical network topology where more powerful fixed or mobile relays are used to collect and route the sensor data to a sink.

A routing protocol will be considered adaptive if it can adapt to the current network conditions and available energy levels. In addition, these protocols can be based on multi-path routing, query, negotiation, or quality of service, among others depending on the protocol functioning. In the networks employing flat routing protocols, every node usually plays the same role of sensing the event. Due to the large number of nodes, assigning a global identifier to each node is not feasible. Adhoc On-demand Distance Vector routing (AODV) is an example of reactive flat routing protocol.

Adhoc On-demand Distance Vector (AODV): AODV is a reactive routing or on-demand routing protocol, since it does not maintain route information nodes if there is no communication. If a node wants to send a packet to another node then it searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet. This protocol performs route discovery process whenever a node wishes to send packets to destination by using control messages route request (RREQ) and route reply (RREP). Neighbourhood information is obtained from broadcasted hello packets. It is a flat routing protocol which does not need any central administrative system to handle the routing process. The AODV protocol is a loop free and uses sequence numbers to avoid the infinity counting problem which is typical to the classical distance vector routing protocols [26].

Route Discovery in AODV: When a node wants to send a packet to some destination node and does not have a valid route in its routing table for that destination, then 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 from its neighbour attaches Destination address, Sequence number and Broadcast ID and then forward the request to its neighbours by flooding new RREQ message. This process of forwarding RREQ message continues until it reaches the destination node. Each node receiving the route request sends a route reply message back (RREP) to the previous node as shown in the figure 1.

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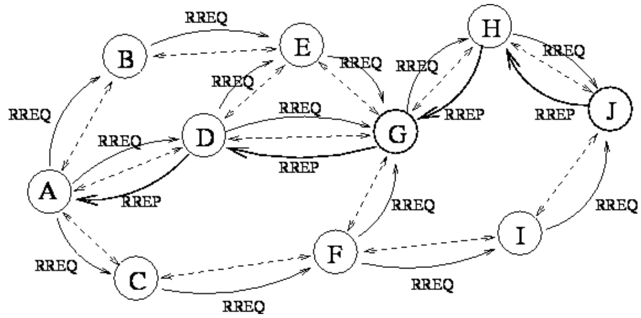

Fig 1. Route Discovery in AODV protocol

A route is established if the RREQ message reaches either the destination itself, or an intermediate node with a valid route entry for the destination. As long as a route is established between source and destination node, AODV remains passive. When the route becomes invalid or lost, AODV will again issue a new request.

AODV uses three types of control messages for its route maintenance:

RREQ - A route request message is transmitted by a source node to find path towards a destination node. As an optimization AODV uses an expanding ring technique when flooding these messages. Every RREQ carries a time to live (TTL) value that states for how many hops this message should be forwarded. This value is set to a predefined value at the first transmission and increased at retransmissions. Retransmissions occur if no replies are received. Data packets waiting to be transmitted (i.e. the packets that initiated the RREQ) should be buffered locally and transmitted by a FIFO principle when a route is set.

RREP - A route reply message is unicasted back to the originator of a RREQ if the receiver is either the node using the requested address, or it has a valid route to the requested address. The reason one can unicast the message back, is that every route forwarding a RREQ caches a route back to the originator.

RERR - Nodes monitor the link status of next hops in active routes. When a link breakage is detected in an active route, a route error (RERR) message is used to notify other nodes about the loss of the link. In order to enable this reporting mechanism, each node keeps a precursor list, containing the IP address for each of its neighbours that are likely to use it as a next hop towards each destination.

When the RREQ is received by a node that is either the destination node or an intermediate node with a fresh enough route to the destination, it replies by unicasting the route reply (RREP) towards the source node. As the RREP is routed back along the reverse path, intermediate nodes along this path set up forward path entries to the destination in its route table and when the RREP reaches the source node, a route from source to the destination established.

Route Maintenance in AODV: A route established between source and destination pair is maintained as long as needed by the source. When a link breaks in an active routing path, the broken link is invalid and a RERR message is sent to other nodes. These nodes in turn propagate the RERR to their precursor nodes and so on until the source node is reached. The affected source node may then choose to either stop sending data or reinitiate route discovery for that destination by sending a new RREQ message.

IV. PROPOSED PROTOCOL

In this paper, an optimised route search protocol Adhoc On-demand Link Quality Aware Route Search Protocol (AO-LQARSP) is proposed for IEEE 802.15.4 standard to address the need of a stable route to improve the throughput in a power scarce WSNs.

Consider a scenario of WSN (figure 2), in which sensor nodes are placed randomly. In order to transfer data packets from source node (node-1) to the destination node (node-17) and if, the source node (node-1) does not have any valid route to the destination in its routing table, then it need to establish a route to the destination node (node-17). In the process of route discovery, source node (node-1) floods the Route Request (RREQ) message along with LQI=0 and hop count=0. The nodes which are in the radio range of source node (nodes 2, 3, 4, 5 and 6) receive the RREQ message with initial LQI=0 and hop count=0 and at each node LQI_{ij} value is calculated using the equation 1 [26,27].

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

Where, **i** is the node ID which floods the RREQ massage and **j** is the node ID which receives the RREQ message. In equation 1, Received Message Power is the value of signal strength received for the corresponding RREQ 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.

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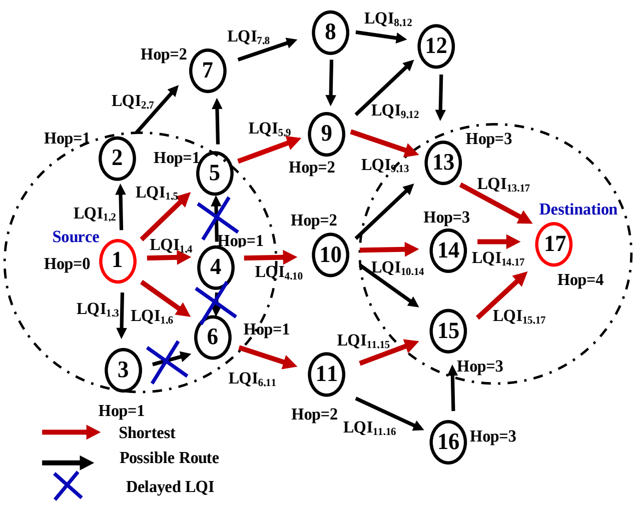

Fig 2. Scenario of route discovery in proposed protocol

Also, aggregate value of LQI (LQI_{agg}) is calculated at these nodes (2, 3, 4, 5 and 6) by adding received LQI value from the previous node (LQI_{Rx}) and LQI value calculated at the current node (LQI_{ij}) (equation 2) i.e.,

$$LQI_{agg} = LQI_{Rx} + LQI_{ij} \qquad (2)$$

These nodes (2, 3, 4, 5 and 6) broadcast RREQ message with corresponding LQI_{agg} and incremented hop count to their neighbouring nodes. Further, nodes (7, 9, 10 and 11) receive the RREQ message from the respective predecessor nodes, calculate the LQI_{ij} value for the first RREQ message received and subsequent RREQ messages are ignored. The LQI_{agg} value is calculated at each node for the first RREQ message using equation 2 and then broadcast the RREQ message with updated LQI_{agg} and incremented hop count to their neighbours. Similar process of flooding RREQ messages has been carried out by all other subsequent receiving nodes till these messages reach the destination node.

At the destination node, when it receives first RREQ message it initiates the timer with delay period of 500ms and waits to receive RREQ messages from other possible routes. Meanwhile, destination node calculates average LQI (LQI_{av}) for each received RREQ message corresponding to possible route within delay period (500ms) using the equation 3.

$$LQI_{av} = \frac{LQI_{agg}}{\text{Hop Count}} \qquad (3)$$

The destination node then opts for the path with larger LQI_{av} value among all possible paths. Further, destination node establishes a route by sending route reply (RREP) message to the source node through all the active nodes involved in the route with higher LQI_{av}. Figure 3 shows the flowchart of the proposed protocol.

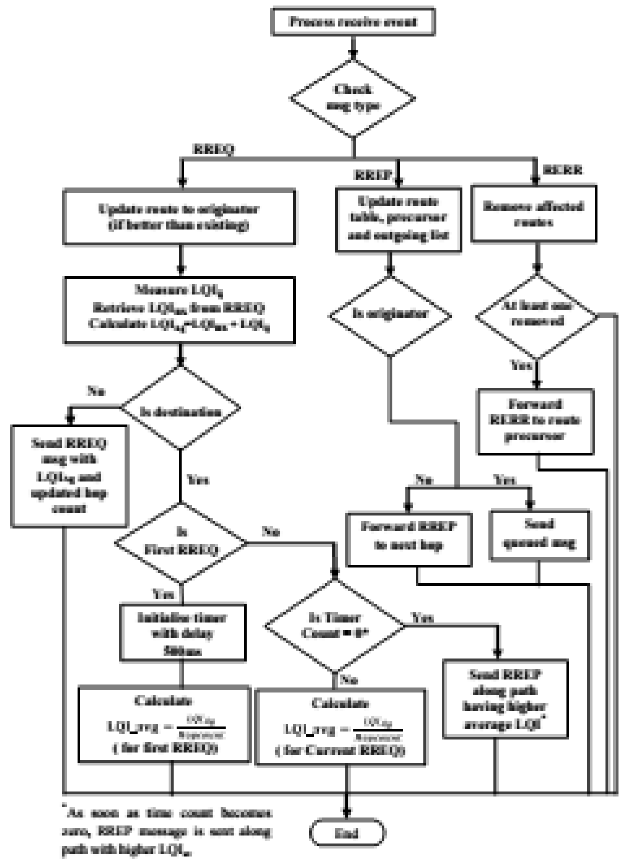

Fig 3. Flowchart for the proposed AO-LQARSP algorithm

V. SIMULATION RESULTS AND DISCUSSIONS

The simulation studies are carriedout by considering proposed routing protocol with varying node density 50, 75, 100, 150, 200 and 250 nodes placed randomly. The simulation study is performed using Qualnet 5.2 network simulator with IEEE 802.15.4 module. Table1 summarizes the parameters considered for simulation study. The simulation studies have been repeated with standard AODV protocol. Figure 4 shows the representative snapshot of Qualnet 5.2 network simulator with 50 nodes for AODV routing protocol.

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Table 1.
Simulation Parameters

Area	1000m x 1000m
Simulation Time	500 second
Number of nodes	50, 75, 100,150, 200 and 250
Nodes Placement	Random
Traffic type	CBR
Energy model	Mica Motes
Battery model	Linear
Radio type	IEEE 802.15.4
No. of Channels	One
Channel frequency	2.4 GHz
Path loss model	Two Ray
Shadowing model	Constant

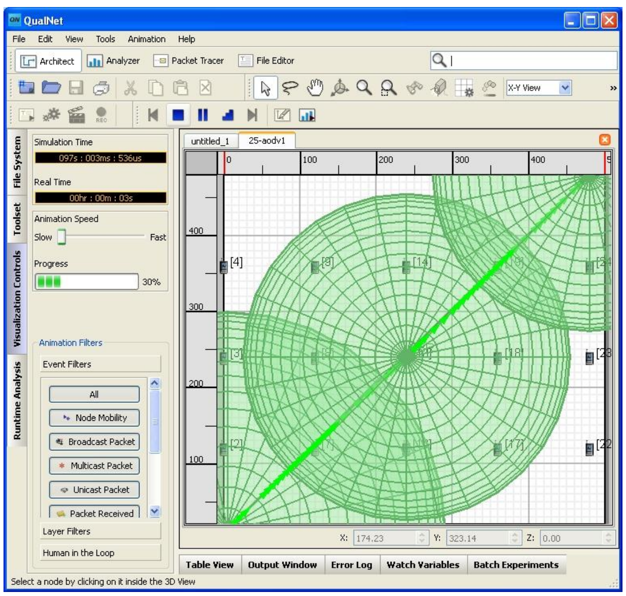

Fig 4. Snapshot of scenario for 50 nodes

Total Packets Received: The variation of total packets received as a function of different node density for the proposed protocol and AODV protocol is shown in figure 5. From figure 5 it is evident that, proposed protocol shows improvement in the packets received as compared with standard AODV. This is because, in the proposed protocol stable route is opted based on larger average LQI value which minimises the packet loss.

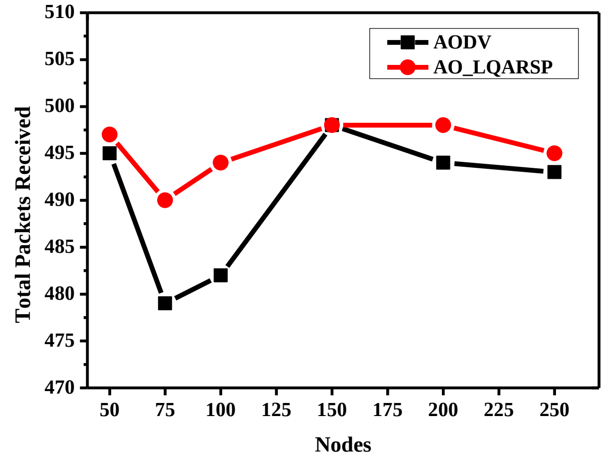

Fig 5. Variation of Total Packets received with varying node density

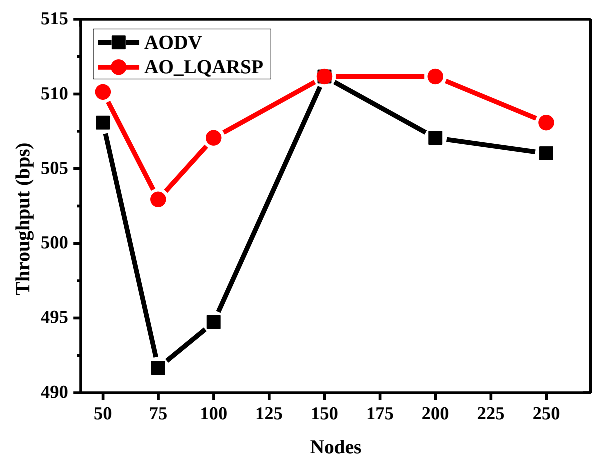

Fig 6. Variation of Throughput with varying node density

Throughput: Figure 6 shows the variation of throughput as a function of node density for AO-LQARSP and AODV protocols. From the figure 6, it is clear that, in proposed protocol the throughput is enhanced as compared to AODV protocol and it is also evident that throughput is stabilised with increase in node density for proposed protocol.

Total bytes received: Variation of total bytes received at the destination node with varying node density for AO-LQARSP and AODV protocols is shown in figure 7. From figure 7 it is evident that, in implemented protocol due to the selection of better stable route more data bytes are received at destination as compared with AODV protocol.

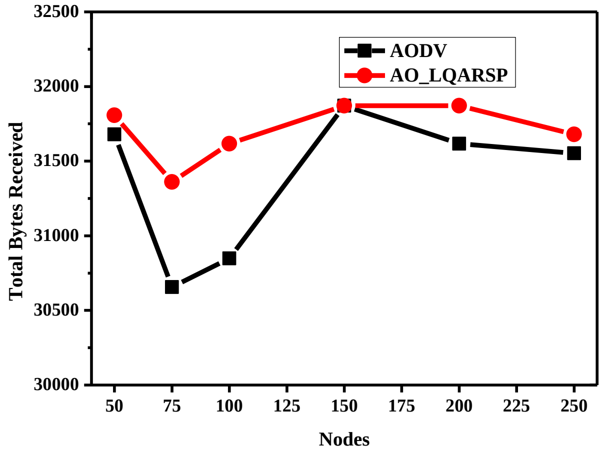

Fig 7. Variation of Total bytes received with varying node density

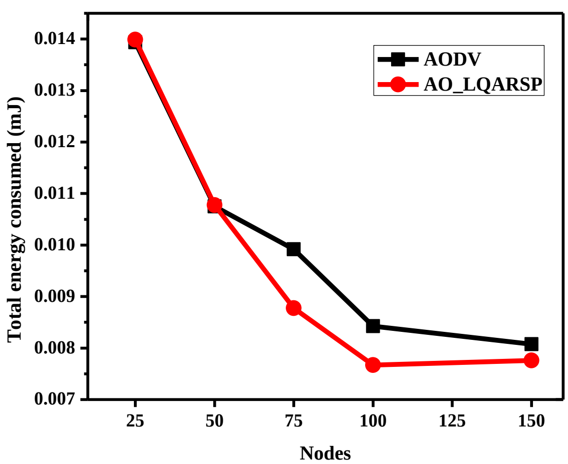

Fig 8. Total energy consumed by nodes with varying node density

Total energy consumed: Figure 8 shows the variation of total energy consumed by all the active nodes along the path of data transmission with node density for implemented protocol and AODV. From the figure 8 it is evident that, total energy consumed in the proposed protocol is marginally less compared to AODV and decreases with increase in node density for both the protocols.

Average end-to-end delay and jitter: Figures 9 and 10 shows the variation of end-to-end delay and jitter with different node densities for implemented AO-LQARSP and standard AODV protocol respectively. It is evident from the figure 9 that, end-to-end delay is almost same for both AO-LQARSP and AODV protocols. The average jitter performance of AO-LQARSP protocol is less compared to AODV protocol (figure 10), this indicates that better and stable route is established in the proposed routing protocol.

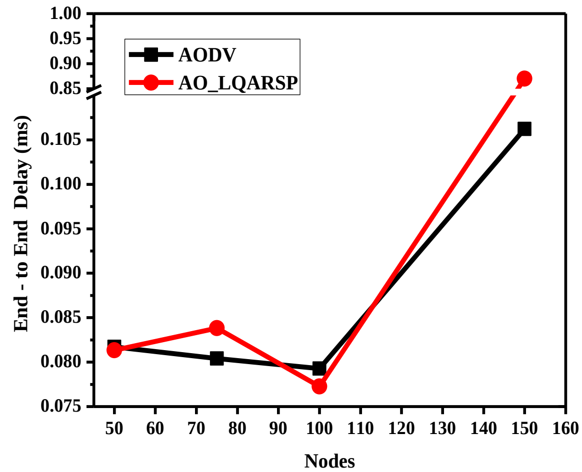

Fig 9. Variation of End-to-End delay with varying node density

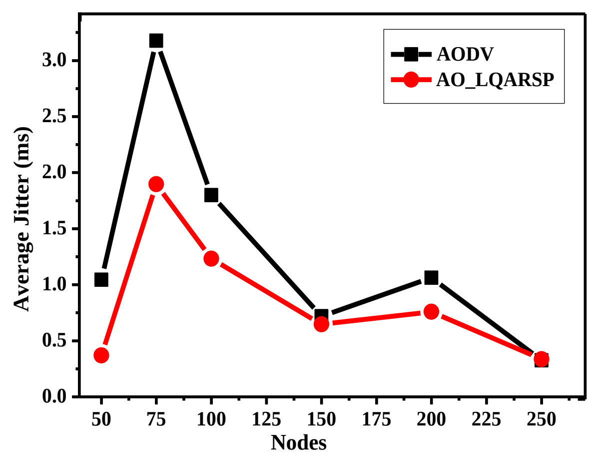

Fig 10. Variation of Average jitter with varying node density

VI. Conclusion

In this paper, a routing protocol is proposed to select the best possible stable route based on link quality indicator. The simulation study of the proposed protocol is carriedout for different node densities. The metrics like throughput, bytes received, end to end delay, average jitter and energy consumed are used to compare proposed AO-LQARSP with standard AODV protocol. From the metrics it is evident that the proposed protocol performs better as compared to AODV.

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, Bangalore and UGC for the author to avail FIP.

Authors would also thank Nihon communication, Bangalore for their support.

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