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Enhanced Load Balancing Routing Protocol to Reduce Energy Consumption in Wireless Sensor Networks

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Abstract: *Wireless Sensor Networks (WSNs) are formed by a very large number of modest power-constrained wireless sensor nodes; it can identify and monitor the changes around them by self. WSNs are implemented in various fields, which include the medical field, army and manufacturing applications. Nodes of WSN are restricted to energy consumption, data storage, and computational power. Routing plays an important role in WSN. Choosing of routing path is considered as important because the choosing of lengthy or congested routing path leads to loss of energy. This paper aims to propose a new routing protocol namely enhanced load balancing routing protocol (ELBRP), which will balance the load in WSN in order to avoid the congestion and reducing the energy consumption. Traditional routing protocols aim either in load balancing or in routing, where the proposed protocol concentrates on both. This research work uses the Network Simulator version 2 (NS2) for evaluation purpose and the performance metrics as throughput, packet delivery ratio, energy consumption, and delay. Results show that the proposed protocol ELBRP achieves its objectives when compared with other approaches namely DACR (Distributed Adaptive Cooperative Routing) protocol and REER (Reliable Energy Efficient Routing) protocol.*

Keywords: *Energy, Load Balancing, Sensor, Routing, Wireless.*

I. Introduction

A sensor is especially a little gadget with exceptionally restricted resources, i.e., energy and memory, which is self-ruling and ready to (i) procure, (ii) process, and (iii) transmit data, utilizing radio waves, to another element over a separation of a few meters. WSN is a kind of ad-hoc network containing sensor nodes which are mobile or static nodes equipped in known or unknown surroundings. Sensors of these types have an energy limit enabling them to work freely and insightfully and to impart by means of radio connection as indicated by setting up a better routing mechanism. Like all ad-hoc networks, WSN is also concerned with the problem of enhanced quality of service in terms of throughput, delay, packet delivery ratio, and reduced energy consumption. WSNs support the improvement of energy requirements as they have constrained resources.

A WSN is actually made out of various nodes with similar jobs, implemented in an organized or ad-hoc operational condition at an elevated risk of breakdown. Breakdowns can originate from an absence of energy resources or physical deficiencies caused by natural elements (like rain, wind, and so on.), which can entangle information transmission. Human interaction or presence is not present at all the times; therefore solutions are expected in this situation. Thus it would exceptionally be intriguing to swing to the utilization and execution of high-level protocols.

WSN involves a huge number of nodes and it encourages the utilization of multi-hop communication which includes low energy utilization and propagation of signals regularly experienced in wireless transmissions. Currently, there exist WSN-type applications which require the use of hundreds or even a great many sensor nodes with the point of guaranteeing network coverage and resolving breakdowns. The probability of one or more neighboring nodes is ready to assume controls from non-operational nodes are high. It can also be said as if nodes arbitrarily implemented in a specified environment are distributed consistently; the dangers of system interference or partition are lower than with an ad-hoc system. Potential issues in data communications or duplication can be overseen.

Most available routing protocols won't exploit the service-oriented architecture over WSNs. Link failures rates are getting increased in WSN, many routing protocols getting proposed in this thrust area but it is not taken any care, where the protocol just finds the alternate paths instead of finding the solution for avoiding the link failure.

Energy consumption is getting high due to network congestion; Congestion is a situation where the performance of WSN gets down in all aspects.

This research aims to propose proficient congestion control mechanism by (i) adjusting the load by passing a message to the nodes, and (ii) avoiding the packet loss by reducing the congestion level that arises in multipath, and (iii) enhancing the throughput, packet delivery ratio; and reducing the delay which aims to result in low consumption of energy. The proposed protocol can give best results in an increased number of nodes and link failure.

II. Literature Review

An energy balancing metric [1] was explored with the diversity in link qualities present at different radios, where its main goal was to effectively utilize the energy of the network to extend the network lifetime. It considers the transmission and reception costs for a specific radio in order to choose an energy efficient radio. Strategy [2] was proposed to balance energy consumption and reduce the energy holes from WSN by balancing the communication load as equally as possible. A mathematical formulation [3] was proposed to support connectivity, flow conservation constraints, data capacity per link, constraints related with communication and sensing range of sensors, and splitting constraints, also balanced energy consumption was focused to prolong the sensors lifetime.

A clustering algorithm [4] namely Distributed Unequal Clustering using Fuzzy logic (DUCF) was proposed for WSN which elects the cluster heads using fuzzy approach. An Energy Efficient Load-Balanced Clustering (EELBC) algorithm [5] was proposed to address energy efficiency as well as load balancing, where EELBC was a min-heap based clustering algorithm. A proposal [6] addresses the WSN issues by adopting a joint approach for routing and channel assignment, where the authors considered a routing part as composed of a heuristic. A hierarchical approach [7] namely distributed energy efficient adaptive clustering protocol with gathering data was proposed for WSN, by default nodes in a sensor network have limited energy, extending the network lifetime. An approach [8] was made significantly improve the main WSN service such as information routing and finally proposed a routing protocol which shares network load traffic among cluster members with the intention of reducing the dropping probability of nodes due to queue overflow at some nodes.

An investigation [9] was made to propose reference routing protocol namely Directed Diffusion, also called as Directed Diffusion with Load Balancing mechanism, which tries to increase load balancing mechanism in order to balance energy utilization in each sensors nodes and also to improve the network lifetime. A load balancing-based hierarchical routing algorithm [10] for WSNs was proposed, by dividing the network by a clustering algorithm, where ant colony optimization is used to find a primary path and some backup paths. A grid-based dynamic load balancing approach [11] was proposed for data-centric storage in sensor networks which relies on dealing with a problem of storage and achieving the load balancing in each node of all the grids. A methodology [12] was presented for the lifetime maximization problem in “many-to-one” and “mostly-off” wireless sensor networks, where all sensor nodes generate and send packets to a single sink via multi-hop transmissions. An effective reconfiguration algorithm [13] was proposed to increase the network lifetime by fairly distributing cluster heads (CHs) in WSN. A load balancing technique [14] was proposed for IEEE 802.11 networks which were based on fuzzy logic in order to ensure the achievement of typical constraints that characterize a wireless scenario. An adaptive learning scheme [15] was proposed for load balancing in multi-sink WSN, where the agent in a centralized mobile anchor with the directional antenna was introduced to adaptively partition the network into several zones to save the energy utilization. A distributed adaptive cooperative routing protocol [16] was proposed for cooperative communication between delay and energy-aware end-to-end routing, which optimizes lexicographic optimization at each hop. Reliable energy-efficient routing protocol [17] was proposed to overcome the problems of scalability, energy consumption and error-resilient routing in WSN.

III. Enhanced Load-Balancing Routing

This section discusses the enhanced load balancing routing protocol proposed for WSN, with the aim of reducing the energy consumption which is considered as the peak issue in this thrust network domain.

3.1 Multipath Multicast Proactive Load Balancing in WSN

This research considers M nodes in WSN, where the topology can be described as the interconnection between M nodes, and it is denoted in a connection diagram as $G(U,F)$, where $V = \{m_i, i = 1, \ldots, M\}$ is the arrangement of nodes and $F \subset U \times U$ denoted as the arrangement of edges in the diagram. Let $R_u(n_i)$ *and* $R_d(n_i)$ signify the transmission range and data carrying sensing scope of node m_i separately. For $m_i \in U$ *and* $1 \le i \le M$, if m_i is inside the transmission scope of m_j and in addition m_j is likewise inside the transmission scope of m_i, at that point the edge $f_{ij} \in E$. As said, based on the WSN model load capacity of the m_i can be defined by

$$U(m_i) = \sum_{o=k}^{K} S_o \quad (1)$$

where K is the total number of paths available and S_o is the default number of packets that can be stored and forwarded at node m_i over path L_{ij}^k.

Considering $Q(L_{ij})$ as the mean the congestion capacity of the routing path between nodes m_i and m_j. At that point, routing paths congestion capacity can be denoted by

$$Q(L_{ij}) = \sum_{p=m_i}^{m_j} U(p) \quad (2)$$

The capacity of the routing path can be denoted as an aggregate load of the path. To describe the load balancing among the distinctive paths, we utilize the equalization factor θ as

$$\theta = \frac{(\sum_{o=1}^{m} W_{bo}^2}{m \sum_{o=1}^{m} W_{bo}^2} \quad (3)$$

To execute the proposed load balancing routing protocol, its necessary for every node to include its load information in HELLO message and after conveying the HELLO message to different nodes to refresh the information of load.

3.2. Congestion Control Method Multipath

The proposed routing protocol maintenance involves two processes namely (a) searching, and (b) identifying the best path from source node to destination node. Link disjoint paths are effectively found by this technique. Link failure may affect a single path only but not all the routing path. In the proposed routing protocol routing path discovery strategy is utilized to find a loop free and link disjoint paths. Intermediate nodes may receive an unknown number of route requests, but these route requests not discarded immediately like other protocols, but the proposed routing protocol accommodates all the route requests in a separate table. All the intermediate nodes from the source to destination make a check for link disjoint. If any disjoint is found, then alternate solution is checked for setting up the new path. Once after finding the alternate paths to the destination, it will send the route reply messages to all the route request messages which are already stored in a separate table. For this situation, the intermediate node will forward the route reply messages to the nodes recorded in the route request table along the most ideal and short path to the source node. In this manner, multiple paths can be found. The proposed routing protocol uses multicasting concept to send the messages to the neighbor nodes which avoids congestion, where other protocols use broadcasting which results in congestion creation. The congestion control method for multipath involves 3 steps, which are: (i) Detection of Congestion; (ii) Controlling and Notifying of Congestion to the Neighbor Nodes, and (iii) Congestion Avoidance and adjustment of load.

A. Detection of Congestion

Congestion detection is the only method to avoid congestion further and delay. Congestion detection is a method to find congestion on the basis of buffer occupancy and load on the wireless channel. Routing path quality rate (RPQR) is the quality of the routing path used to send the sensed data. Average path quality rate (APQR) is the average quality rate of a specific path used to send the sensed data. The quality rate can be viewed as the inverse of path service time $u_s^i(k)$ for path m, it includes the time interval of packet successfully leaving network layer. It tends to be seen that $u_s^i(k)$ covers the time taken by the packet at the network layer which includes waiting time, resolution of a collision, and time of transmission.

B. Controlling and Notifying of Congestion

Readjustment mechanism for finding the alternate paths is done by using hop-by-hop rate. Percentage of output at each node of a specific path is adjusted by scheduling rate. The scheduling rate can be mentioned a number of packets scheduled at a specific time in a queue on a specific path. Following this strategy can decrease the loss of packets. Piggyback concept is utilized to maintain the queue uniqueness.

C. Cancellation of Congestion and adjusting the load.

The congestion avoidance system purges its buffer and lessens the measure of the accumulated size of a packet to enable the present data packet that is to be transmitted before sending the CNGST message to the source node. At the point when a CNGST packet is received by the source node, the conveyance rate is changed in accordance with a lower predefined rate. For a few applications, when the load rate is too low or the source node gets different CNGST messages that cross the threshold limit from one route, it will invoke route rediscovery concept to find some other multipath.

IV. Performance Evaluation

4.1 Simulation Setting

The performance evaluation is done to check how far the proposed protocol performs than the other protocols. This research work conducted the simulation using NS2. NS2 supports multihop wireless networks complete with physical, data link, and MAC layer simulations. The results are compared with DACR [16], and REER [17] protocol. The simulation settings are listed in Table 1.

Table 1- Simulation Setting

Basic specification		***Sensed traffic Specification***	
Network area size	2000 m x 2000 m	Application type	Event-driven
Deployment type	Random	Sources in one event	≈50 Nodes to 250Nodes
Network architecture	Homogeneous and flat	Packet size	64 Byte
Number of nodes	2000	Traffic type	CBR (3 pps)
Sink location	(1000,1000)		
lnitial node energy	10J		
Buffer size	50		
Radio range	100 m		
Sensing radius	52 m		
Link layer trans. rate	512 Kbps		
Transmit power	$7.214e^{-3}$ W		
Rcv. signal threshold	$3.65209e^{-10}$ W		
Link failure rate.	Varying from 0.05 to 0.5		
MAC	lEEE 802.11 DCF		
Number of Nodes	Varying from 50 to 250		
Simulation time	200 s		

4.2 Performance Metrics

This research work uses below-mentioned benchmark performance metrics for evaluating the proposed protocol ELBRP with DACR [16], and REER [17] protocol.

- ✓ Throughput – It is the total amount of data packets successfully transmitted from the source node to sink node in a specified time period. The maximum value is taken or considered as the better performance.
- ✓ Average end-to-end delay – It is the time taken by a packet to travel from sink node to destination node. The time delay faced by each node is averaged over the total number of packets received by the sink. The minimum value is taken or considered as the better performance.
- ✓ Packet Delivery Ratio – It is the percentage of packets received by the sink node within the specified time over the total packets generated by all the nodes in the WSN. The maximum value is taken or considered as the better performance.
- ✓ Energy Consumption – It is the percentage of the total amount of energy taken by the nodes from the source node to the sink node. The minimum value is taken or considered as the better performance.

4.3 Results and Discussion

4.3.1 Analysis of results based on Nodes

Figures 1–4 show the mentioned metrics, in which we simulated the performance of the proposed ELBRP with varying number of nodes from 50 to 250.

4.3.2 Analysis of results based on Link Failure Rates

Figures 5-8 shows the mentioned metrics, in which we simulated the performance of the proposed ELBRP with varying rate of link failures from 0.05 to 0.5.

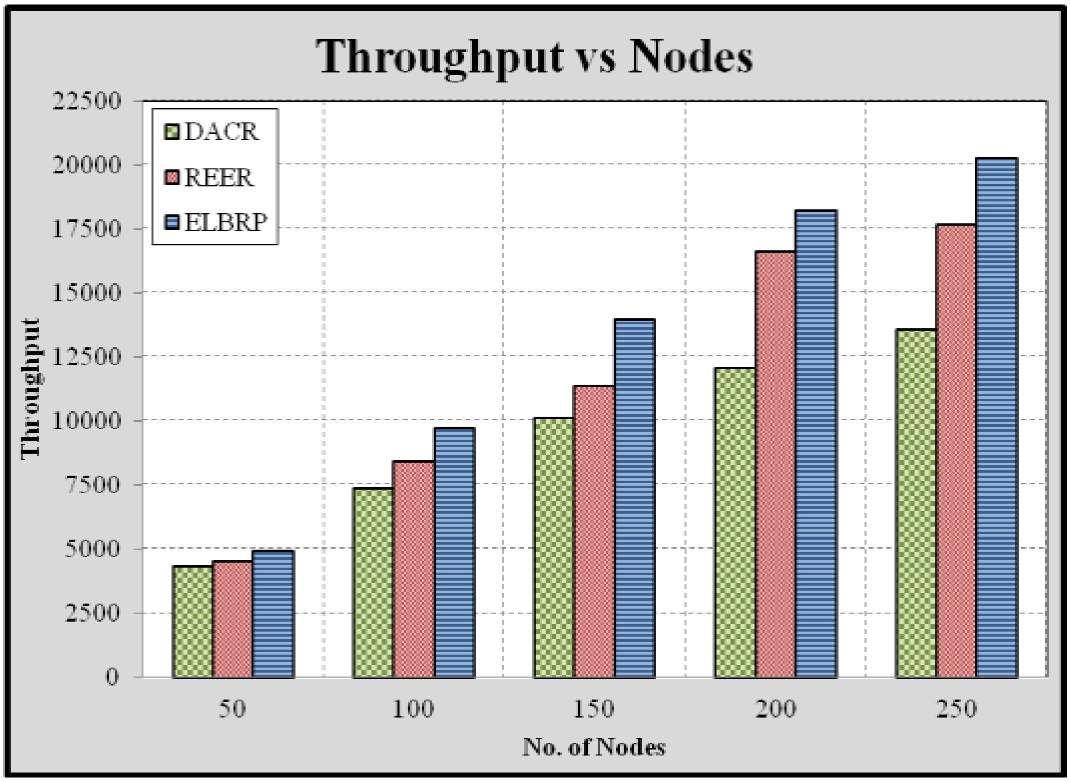

Figure 1. Throughput vs Nodes

Figure 1 shows the throughput of proposed protocol ELBRP, DACR and REER protocols. Comparing with DACR and REER, the proposed protocol ELBRP has higher throughput.

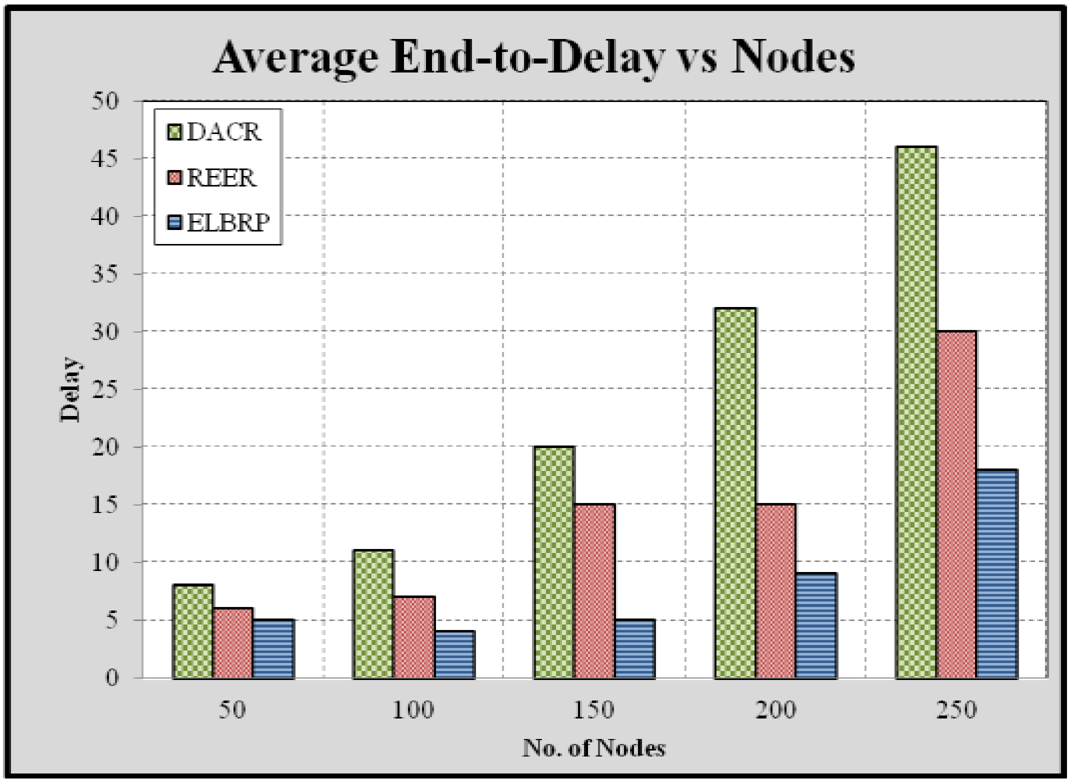

Figure 2. Average End-to-End delay vs Nodes

Figure 2 compares the average end-to-end delay of ELBRP, DACR and REER protocols. From the figure, it is clear that the average end-to-end delay is remarkably lower than DACR and REER. In these simulations, ELBRP achieves the lowest delays compared with DACR and REER, which is due to the fact that ELBRP schedules the load on the paths with larger path vacant ratio which results in lower congestion for data transfer.

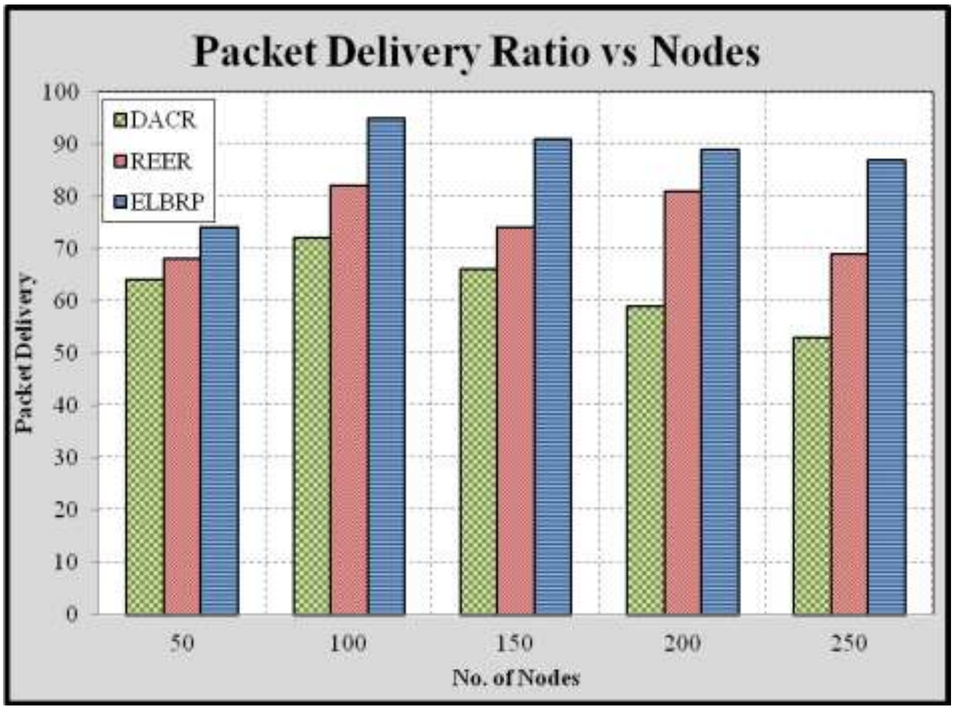

Figure 3. Packet Delivery Ratio vs Nodes

Figure 3 shows the packet delivery ratio of proposed protocol ELBRP, DACR and REER protocols, where a fixed workload is used with constant bit rate (CBR). ELBRP achieves the highest ratio when comparing with DACR and REER.

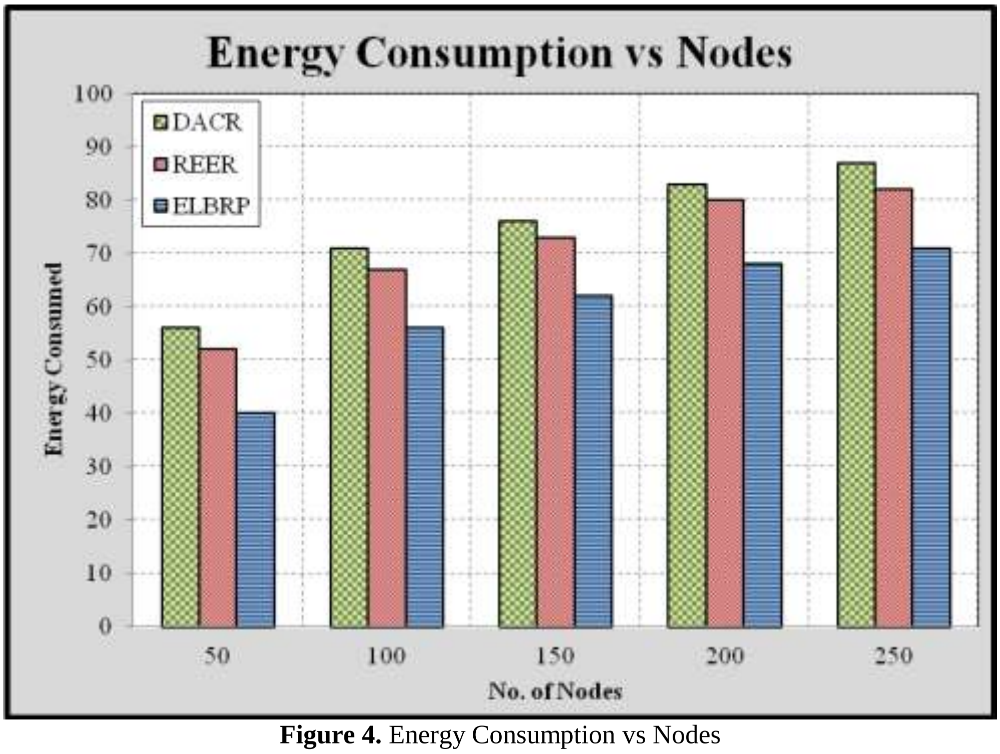

Figure 4. Energy Consumption vs Nodes

Figure 4 shows the energy consumption of proposed protocol ELBRP, DACR and REER protocols, where a fixed energy of 10J is used. ELBRP consumed low energy when comparing with DACR and REER.

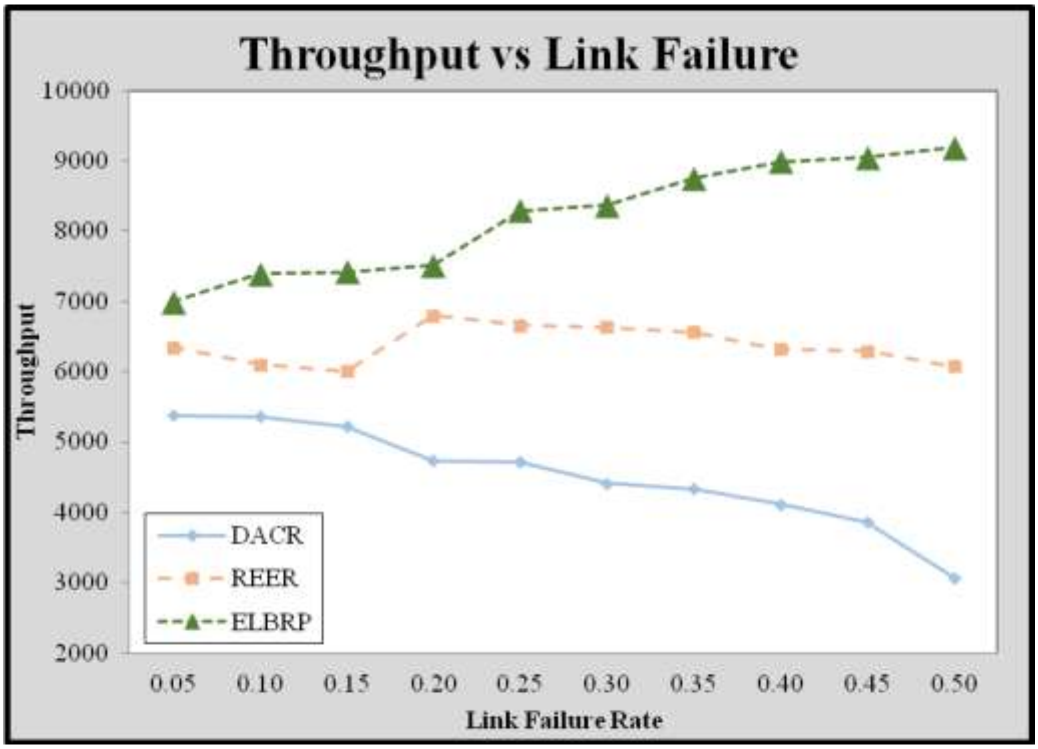

Figure 5. Throughput vs Link Failure

Figure 5 shows the throughput of proposed protocol ELBRP, DACR and REER protocols. Comparing with DACR and REER, the proposed protocol ELBRP has higher throughput in different rate of link failures.

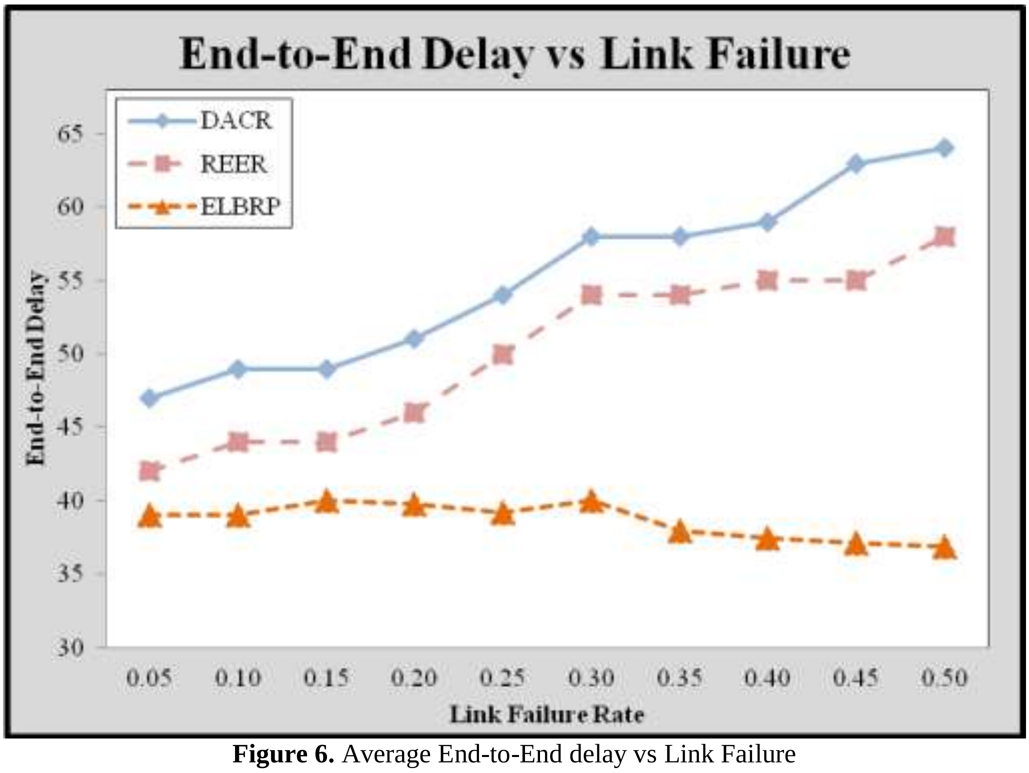

Figure 6. Average End-to-End delay vs Link Failure

Figure 6 compares the average end-to-end delay of ELBRP, DACR and REER protocols. From the figure, it is clear that the average end-to-end delay is remarkably lower than DACR and REER in different rate of link failures. In this simulation, ELBRP achieves the lowest delays compared with DACR and REER.

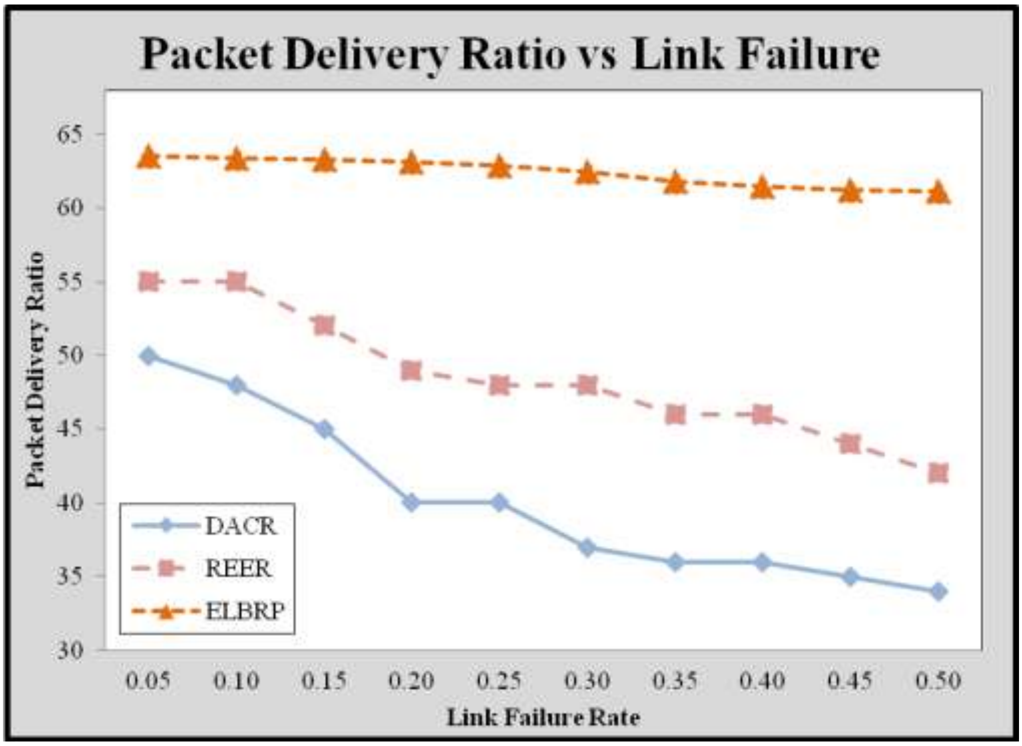

Figure 7. Packet Delivery Ratio vs Link Failure

Figure 7 shows the packet delivery ratio of proposed protocol ELBRP, DACR and REER protocols, where a fixed workload is used with constant bit rate (CBR). ELBRP achieves the highest ratio when comparing with DACR and REER in different rate of link failures.

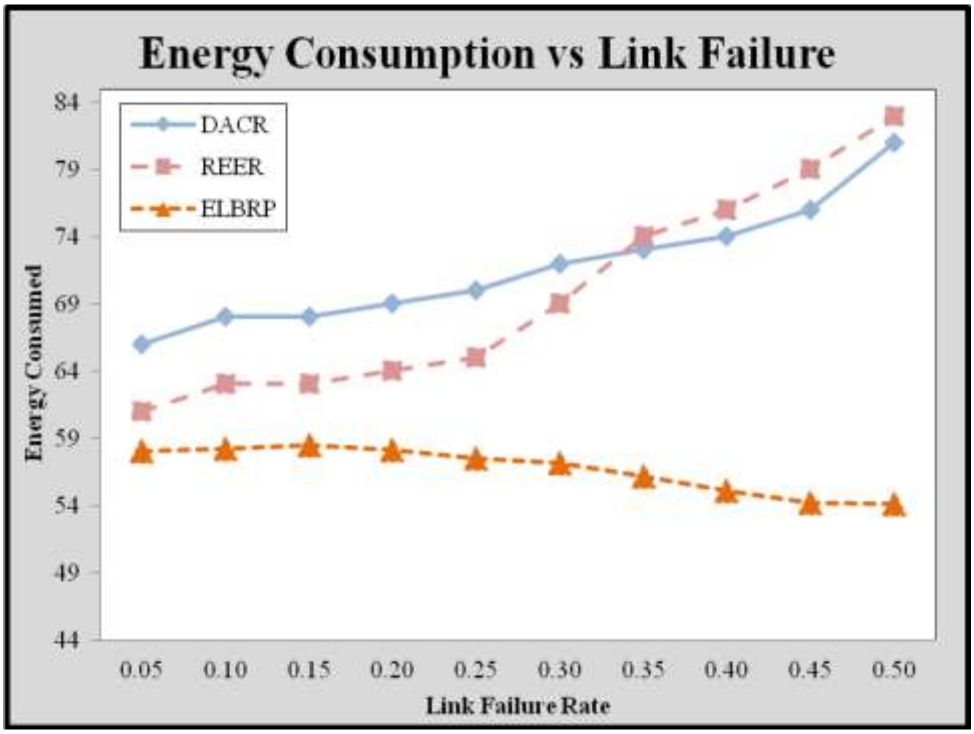

Figure 8. Energy Consumption vs Link Failure

Figure 8 shows the energy consumption of proposed protocol ELBRP, DACR and REER protocols, where a fixed energy of 10J is used. ELBRP consumed low energy when comparing with DACR and REER in different rate of link failures.

V. Conclusion

This research work has proposed a routing protocol for WSN which aims in reducing the congestion and energy consumption by using the concept of load balancing. The proposed protocol ELBRP checks the disjoint links for the enhancing the quality of service. ELBRP involves detection of congestion, notifying of congestion to the neighbor nodes, congestion avoidance and adjustment of the load. This research work uses the benchmark performance metrics throughput, average end-to-end delay, packet delivery ratio, and energy consumption for the performance evaluation purpose. ELBRP is evaluated based on the number of nodes and link failure rate. In both the aspects the ELBRP attains better performance than DACR and REER protocol. The future dimension of this research work can be preceded by using the optimization concept.

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