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Reliable Link Based Energy Efficient Cluster Routing Scheme for Wireless Sensor Networks

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ABSTRACT: Wireless sensor network (WSN) has recently become promising network architecture and is widely used in many applications, including environmental monitoring, object detection, event tracking, and security surveillance. In WSNs, nodes in the area of interest must report sensing readings to the sink, and this report always satisfies the report frequency required by the sink. Reliable Link based Energy Efficient Cluster Routing Scheme is proposed for achieving an energy-efficient and reliable routing path. It consists of four phases. In first phase, the cluster routing is established to ensure load balancing and longer network lifetime. In second phase, multipath routing is deployed with clustering to avoid network failures and congestion. In third phase, the path stability and energy consumption of wireless sensor nodes are determined. In this phase, the energy consumption threshold model is developed and mathematical model of path reliability is proposed. By simulation results, the proposed RLEECRS achieves better end to end delivery ratio, improved network lifetime, less packet delay and energy consumption in terms of mobility, time and number of nodes than the existing scheme LCM

KEYWORDS: WSN, RLEECRS, Multipath routing, energy consumption, path reliability, network lifetime, delay, energy consumption, throughput and end to end delivery ratio.

I. INTRODUCTION

A. Wireless Sensor Networks (WSNs)

A wireless sensor network (WSNs) consists of a large number of light weight sensor nodes having limited battery life, computational capabilities, storage, and bandwidth. These low-cost sensor nodes can be deployed either randomly by dropping from an airplane or precisely using manual deployment. These sensor nodes sense a change in the environmental or a physical quantity and transmit this data to the base station, also referred to as a sink node. A WSN is made of large number of low cost sensor nodes with processing and communication capabilities. While sensors are small devices with limited power supply, a WSN should operate autonomously for long periods of time in most applications. In order to better manage energy consumption and increase the whole network lifetime, suitable solutions are required at all layers of the networking protocol stack. In particular, energy aware routing protocols at the network layer have received a great deal of attention since it is well established that wireless communication is the major source of energy consumption in WSN.

The network layer in WSN is responsible for delivery of packets and implements an addressing scheme to accomplish this. It mainly establishes paths for data transfer through the network. Compared to traditional ad-hoc networks, routing is more challenging in wireless sensor networks due to their limited resources in terms of available energy, processing capability and communication, which are major constraints to all sensor networks applications. These

constraints yield frequent topology changes making route maintenance to be a non-easy task. Additionally, the typical mode of communication is many-to-one, from multiple sources to a particular sink rather than from one entity to another. Finally, since data related to one phenomenon may be collected by multiple sensors, a significant redundancy is likely to be present and has to be considered.

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B. Design goals of Wireless Sensor Networks WSNs)

Based on the application, different architecture, goals and constraints have been considered for WSNs. The following design goals of Wireless Sensor Networks are given below.

a. Energy Considerations

During the creation of an infrastructure, the process of setting up the routes is greatly influenced by energy considerations. Since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacles, multihop routing will consume less energy than direct communication. However, multi-hop routing introduces significant overhead for topology management and medium access control. Direct routing would perform well enough if all the nodes were very close to the sink. Most of the time sensors are scattered randomly over an area of interest and multi-hop routing becomes unavoidable.

b. Node deployment

Node deployment in WSN is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths; but in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. Hence, random deployment raises several issues as coverage, optimal clustering etc. which need to be addressed.

c. Energy consumption without losing accuracy

Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime. In a multi-hop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

d. Data Aggregation/Fusion

Since sensor nodes might generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions would be reduced. Data aggregation is the combination of data from different sources by using functions such as suppression (eliminating duplicates), min, max and average. In some network architectures, all aggregation functions are assigned to more powerful and specialized nodes. Data aggregation is also feasible through signal processing techniques. In that case, it is referred as data fusion where a node is capable of producing a more accurate signal by reducing the noise.

II. RELATED WORK

In this paper [1], it is proposed that a distributed and energy efficient protocol, called TBRP for data gathering in wireless sensor networks. In this method, cluster head is selected with considering the distance to the neighborhoods and the residual energy of node, and it is defined new algorithm for cluster head election. It can better handle heterogeneous energy circumstances than existing clustering algorithms which elect the cluster head only based on a node's own residual energy. After the cluster formation phase, it constructs a fuzzy spanning tree over all of the cluster heads. Only the root node of this tree can communicate with the sink node by single-hop communication. Because the energy consumed for all communications in in-network can be computed by the free space model, the energy will be extremely saved and thus leading to sensor network longevity.

Nurhayati [2] proposed a Cluster Based Energy Efficient Location Routing Protocol (CELRP) in Wireless Sensor Networks that utilizes high-energy of the Base Station (BS) to perform most energy efficient task. By using BS, the sensor nodes are relieved from performing energy intensive computational task such as cluster setup, cluster head selection and routing formation. The sensor nodes are made into clusters and divided into different quadrants. Each quadrant contains two clustering and sensor nodes that transmit data with two hops data transmission. CH is selected based on the node with maximum residual energy and minimum distance to the base station in each cluster. The CH with the highest energy residual is chosen as the CH Leader between all the other CHs.

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In this paper [3], the proposed routing protocols employ various approaches i.e. flooding based approach, multipath based approach and cluster based approach. It is classified that the state-of-the-art routing protocols based on these approaches.

Chang [4] presented that Energy-Aware, Cluster Based Routing Algorithm (ECRA) for wireless sensor networks to maximize the network's lifetime. It selects some nodes as cluster-heads to construct Voronoi diagrams and rotates the cluster-head to balance the load in each cluster. A two-tier architecture (ECRA-2T) is also proposed to enhance the performance of the ECRA. This algorithm includes three phases: clustering, data transmission and intra-cluster-head rotation. In this work, it is assume that the sensors are location-aware. This algorithm selects some nodes as cluster-heads to construct a Voronoi diagram. The sensor nodes transmit their sensing data to cluster-heads which forward the aggregated data to the sink node. Then, in the next round, it chooses a sensor node from the previous cluster as a cluster-header, called an intra-cluster-head rotation.

Quan et.al [5] proposed a robust energy-aware clustering architecture (REACA) for large-scale wireless sensor networks. This architecture supports data aggregation and enables access to information of interest from data collected by spatially distributed sensor nodes. Applications include the average temperature of a field, an anomaly in a surveillance network, and the location of a particular event, etc. It is analyzed that the performance of the REACA network in terms of quality-of service, throughput capacity, and power consumption.

Jalil et.al [6] proposed an Extending Lifetime of Cluster Head routing protocol that has self-configuration and hierarchal routing properties. It reforms the existing routing protocols in several aspects and constructs clusters on the basis of radio radius and the number of cluster members. In this method, the clusters in the network are equally distributed.

In this paper [7], QoS routing is enhanced in wireless sensor networks by using delay along with the transmission energy. The performance of this scheme was evaluated through analytical and simulation techniques and the results were shown an increase in sensing node lifetime with the number of clusters, but with a corresponding increase in end-to-end delay.

Jiguo et.al [8] proposed a cluster-based routing protocol for wireless sensor networks with non uniform node distribution. This protocol constructs clusters of even sizes using competition range in order to balance the energy consumption among cluster members. To solve the imbalanced energy consumption among cluster heads caused by the non uniform node distribution, a cluster-based routing algorithm is proposed, which balance the energy consumption among cluster heads by adjusting the intra-cluster and inter-cluster energy consumption of cluster heads. This protocol achieved the balance of energy consumption among nodes and prolongs the network lifetime.
In this paper [9], a new cluster based routing protocol referred to as Energy Aware Cluster-based Multihop (EACM) Routing Protocol is introduced, with multihop communication between cluster heads for transmitting messages to the base station and direct communication within clusters. This scheme contains both static and dynamic clustering. The network is partitioned into near optimal load balanced clusters by using a voting technique, which ensures that the suitability of a node to become a cluster head is determined by all its neighbors.

Neha jain [10] presented a study of different protocols which are used in increasing energy efficiency of the Wireless Sensor Network such as LEACH(Low Energy Adaptive Clustering Hierarchy),CB-DHRP(Cluster Based Directed Hierarchical Routing Protocol),BCBE(Balanced Cluster and Balanced Energy). In wireless sensor network such as LEACH,BCBE and CB-DHRP.BCBE and CB-DHRP routing protocol provides improvement over LEACH and achieve the longer network lifetime.

Lee et.al [11] proposed a cluster-based energy-aware routing protocol without location information of the sensor nodes for sensor networks. In this protocol, the focus was placed on the fact that all sensor nodes do not necessarily know their own position. Moreover, to send information on their position every cluster construction phase may cause unnecessary overheads. However, it is desirable to send their information with their sensing data in order to construct optimal clusters. Therefore, the proposed protocol constructs clusters without inefficient sensor-node-broadcasts to

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notify the base station of the information of each sensor node. In addition, the proposed protocol changes the desirable number of cluster-heads when composing optimum clusters.

Ghosh et,al [12] presented a cluster based routing algorithm. This algorithm makes the best use of node with low number of cluster head know as super node. Here it divided the full region in four equal zones and the center area of the region is used to select for super node. Each zone is considered separately and the zone may be or not divided further that's depending upon the density of nodes in that zone and capability of the super node. This algorithm forms multilayer communication. The number of layer depends on the network current load and statistics.

In this paper [13], it is examined that the optimization of the lifetime and energy consumption of Wireless Sensor Networks (WSNs). These two competing objectives have a deep influence over the service qualification of networks and according to recent studies, cluster formation is an appropriate solution for their achievement. To transmit aggregated data to the Base Station (BS), logical nodes called Cluster Heads (CHs) are required to relay data from the fixed-range sensing nodes located in the ground to high altitude aircraft. This study investigates the Genetic Algorithm (GA) as a dynamic technique to find optimum states.

Golam et.al [14] developed a two layer hierarchical routing protocol called Cluster Based Hierarchical Routing Protocol (CBHRP). It is introduced a new concept called head-set, consists of one active cluster head and some other associate cluster heads within a cluster. The head-set members are responsible for control and management of the network.

S.Barani and Dr.C.Gomathy [15] introduced energy aware routing algorithm for wireless sensor networks. Protocol is based on fuzzy logic computation reduces power consumption by the ratio of 10 when compared to classical routing protocol. Proposed protocol is implemented in two phases, first phase being computation of neighbor node and updating of routing table and route establishment is done in second phase. Consumption of energy is considerably reduced on properly designed protocol.

Wang and Chen [16] proposed a link-aware clustering mechanism, called LCM, to provide energy-efficient routing in wireless sensor networks. It introduces the predicted transmission count (PTX) to assist in constructing cluster structures. The PTX represents the level of report quality that nodes can support and is derived from the transmit power consumption, residual energy, and link quality. The key concept of this scheme is to use the PTX as a primary clustering metric to determine a priority for each CH or GW candidate. Based on the derived priority, the LCM can select the best nodes to become cluster heads or gateways.

The paper is organized as follows. The Section 1 describes introduction about WSNs, data gathering and issues. Section 2 deals with the previous work which is related to the data gathering algorithms. Section 3 is devoted for the implementation of proposed scheme. Section 4 describes the performance analysis and the last section concludes the work.

III. IMPLEMENTATION OF PROPOSED SCHEME

In our proposed Reliable Link Energy Efficient Cluster Routing Scheme, reliability and quality of path us determined based on energy level of sensor node. In first phase, cluster routing is established to ensure load balancing and longer network lifetime. In previous routing protocol, random election of ensure their field even distribution in sensing area. In second phase, multipath routing with hop to hop authentication to ensure load balancing and avoid network failures. In third phase determination of path reliability is done using mathematical model. In fourth phase, Energy consumption model is proposed to keep high energy efficiency of wireless sensor nodes.

Phase I : Establishing cluster routing

In this phase, cluster consists of sensor nodes and cluster heads are elected based on high energy level. In this case, cluster members are likely to exhaust their energy more quickly which may lead to insufficient coverage and network

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disconnection. Cluster heads which are in distributing region, regularly meet to update communication status. Cluster heads are periodically selected according to a hybrid of their residual energy and intra-cluster communication cost. In order to limit cluster head initial announcements, starting percentage C_{prob} of cluster heads among all sensors are determined.
Probability of sensor nodes becomes a cluster head is calculated as

$$CH_{prob} = C_{prob} * \left(\frac{E_{residual}}{E_{\max}} \right) \qquad (1)$$

$CH_{prob} = C_{prob} E_{residual}/E_{max}$
where $E_{residual}$ is the current energy in the sensor, and E_{max} is its maximum energy. Afterwards, every sensor goes through several iterations until it finds the cluster head that it can transmit to with the least transmission power. If it hears from no clusterhead, the sensor elects itself to be a cluster head and sends an announcement message to its neighbors. Each sensor doubles its CH_{prob} value and goes to the next iteration until its CH_{prob} reaches 1. Therefore, there are two types of status that a sensor could announce to its neighbors:

• **Cautious status:**
The sensor node becomes a tentative cluster head if its CH_{prob} is less than 1. It can change its status to a regular node at a later iteration if it finds a lower cost cluster head.
• **Closing status:** The sensor node permanently becomes a cluster head if its CH_{prob} has reached 1. At the final phase, each sensor makes a final decision on its status. It either picks the least cost cluster head or pronounces itself as cluster head. In each iteration, a lot of packets are broadcast. Each sensors calculates its weight after locating the neighboring nodes in its area using,

$$F_{weight}(r) = \frac{E_{rem}(r)}{E_{start}(r)} \times \sum_{L} \frac{Q-d}{5Q} \qquad (2)$$

where $E_{rem}(r)$ and $E_{start}(r)$ are respectively remaining and starting energy at node s, Q is the cluster range where system parameter that corresponds to how far a node inside a cluster can be from the cluster head and d is the distance between source node C and neighboring node L. In a neighborhood, the node with largest weight and energy consumption would be elected as a cluster head and the remaining nodes become members. At this stage, cluster member nodes are considered as N-1-level nodes and communicate directly with the cluster head. If a member node can reach its cluster head using more than one hop while saving energy, it will become an h level member where h is the number of hops required to achieve the cluster head. Required energy to communicate in a cluster can be computed using node's knowledge of the distance to its neighbor sensor nodes. The cluster range Q is used to limit the number of levels.

Phase II : Multipath Routing

In the proposed multipath routing scheme, the network is organized as a collection of Cluster node. Each cluster has its own cluster head. The cluster head is chosen based on the higher priority depends on communication status among the nodes, bandwidth, frequency, energy level. If two cluster participant nodes m_1, m_2 want to communicate between different regions, they need to get permission from CH_1, CH_2. In the proposed scheme, certain constraints are to be followed.

- The node in Cluster (C), only if the hop count is below the node's hop value.
- Each node should have minimum four multiple paths to reach the particular destination D.
- The energy level of the clusters is determined based on the energy level of cluster nodes. The threshold energy level is calculated by cluster head (CH).
- The RREQ message is transmitted when the source node is reached and to create a new entry in the local routing neighbor table.

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In this phase multi path data transmission is initiated where each cluster member sensor node B_i discovers the possible paths to reach its data collector node. Let D denote the path from node B_i to the base station (*BS*). Also, let node M_j be the first data collector on path D between B_i and *BS*. Here local paths are determined based on number of disjoint paths from B_i to M_j . Moreover B_i discovers its local path set using the Local Path Discovery procedure. Hence there is *n* paths that connects sensor node B_i to its data collector M_j . Even though number of paths is established, multi path data transmission is deployed when B_i has a low energy consumption level and reputation value which indicates there may be possible compromised nodes in the neighborhood. Whenever this situation happens, B*i* first decides the number of paths to send the data, say *k*, then select *k* most reliable paths from its local path set.

Input: Data collector M_j , cluster member sensor node B_i and B_i's neighboring nodes.

Output: Local path set from B_i to M_j .

Step 1: B_i broadcasts a small route request message L_{rreq} that has destination address M_j .

Step 2: Each one of B_i's neighboring nodes forwards an L_{rreq} message towards *j* after adding its ID to L_{rreq}. *j* receives a number of L_{rreqs} with a list of nodes that relayed the L_{rreq}.

Step 3: M_j replies to each L_{rreq} with an L_{rrep} message along with the ID list of L_{rreq}.

Step 4: Each L_{rrep} message follows the same path of its L_{rreq}. B_i receives each L_{rrep} message along with the ID lists. Each ID list refers to a path B_i to M_j .

Step 5: B_i selects n paths and saves those paths as its local path set to data collector M_j.

Phase III: Determination of path reliability and energy consumption

In our scheme, multipath routing is deployed to improve the reliability of data transmission by sending duplicated data via multiple paths. It means that packet is delivered to the destination even if some paths fail. To improve the reliability of path and data transmission while respecting the network energy constraint, redundancy is applied using erasure coding on multipath routing. The key of this scheme is send more fragments, *N + W*, than the minimum required fragments, *N*, to recover the original packet at the sink. In our proposed routing mechanism, the reliability of data transmission, the successful end-to end data delivery, is achieved by sending the fragments of RS codeword on *mq* selected node-disjoint multipath and to guarantee that the codeword packet is recoverable from any [*mq*/2] paths to ensure that fragments allocation on any [*mq*/2] paths is given as follows,

$$\sum_{i=1}^{[mq/2]} y_i \geq N \qquad (3)$$

The path is series of links and path delay where the delay between the source node and neighbor node given by the sum of link delays

$$W(p) = \sum_{i=1}^{\in} d(r_i, r_{i+1}) \qquad (4)$$

$d(r_i, r_{i+1})$ is the delay of data over the link.

Energy Consumption between node r_i and node r_{i+1} is given as

$$E(p) = \sum_{i=1}^{\in} \chi(r_i, r_{i+1}) \qquad (5)$$

$\chi(r_i, r_{i+1})$ is the energy required to receive and transmit data between node r_i and node r_{i+1} .

The necessary and minimum energy per bit for a node r_i to receive a bit and transmits to the node r_{i+1} is given by

$$\chi_i(r_i, r_{i+1}) = \beta_1 + \beta_2 \| y_{r\,i} - y_{r\,i+1} \|^n \qquad (5)$$

β_1 - energy per bit consumed by the transmitter

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β_2 - energy per bit consumed by the receiver.

The condition for minimum energy per bit to sensor nodes is given by,

$$\min \sum_{i=1}^{\in} \chi(r_i, r_{i+1}) = f_{r_i \to r_{i+1}} \bullet \chi_i(r_i, r_{i+1}) \quad (6)$$

IV. PERFORMANCE ANALYSIS

We use Network Simulator (NS2) to simulate our proposed algorithm. Network Simulator-2(NS2) is used in this work for simulation.NS2 is one of the best simulation tools available for Wireless sensor Networks. We can easily implement the designed protocols either by using the otcl coding or by writing the C++ Program. In either way, the tool helps to prove our theory analytically.

In our simulation, 101 mobile nodes move in a 1000 meter x 1000 meter square region for 60 seconds simulation time. All nodes have the same transmission range of 250 meters. Our simulation settings and parameters are summarized in table 2.

Table2. Simulation settings and parameters of proposed algorithm.

No. of Nodes	101
Area Size	1000 X 1000
Mac	802.11
Radio Range	250m
Simulation Time	60 sec
Traffic Source	CBR
Packet Size	80 bytes
Mobility Model	Random Way Point
Transmitter Amplifier	150 pJ/bit/m^2
Package rate	4 pkt/s
Protocol	LEACH

A. Performance Metrics

We evaluate mainly the performance according to the following metrics.

End-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Path Reliability Rate: It is defined as to ensure path has never been corrupted or broken.

Overhead: It means that ratio of number of routing control packets to the normalized packets.

Throughput: It is defined as the number of packets received at a particular point of time

The simulation results are presented in the next part. We compare our proposed algorithm (RLEECRS) with LCM [16] in presence of energy consumption.

Figure 3 shows the results of energy consumption for varying the simulation time from 10 to 50. From the results, we can see that RLEECRS scheme has minimal energy consumption than the LCM scheme.

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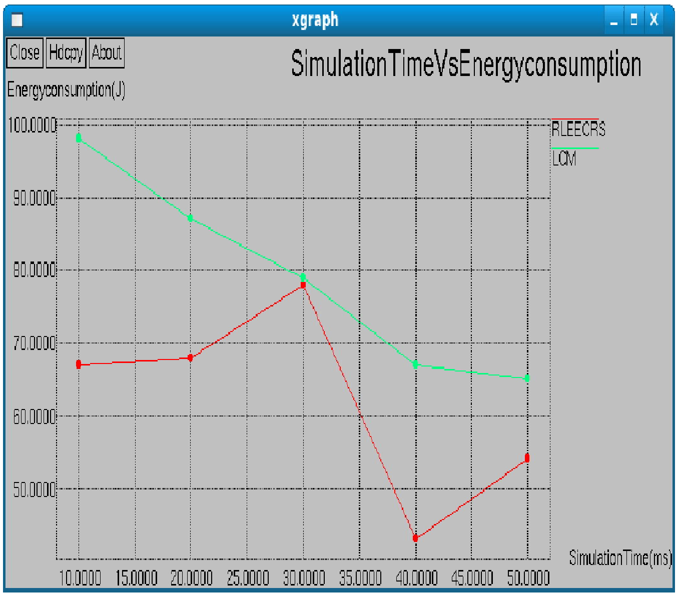

Fig. 3. Time Vs Energy consumption

Fig. 4, presents the network lifetime comparison for RLEECRS, LCM. It is clearly seen that number of epochs consumed by RLEECRS is high compared to LCM.

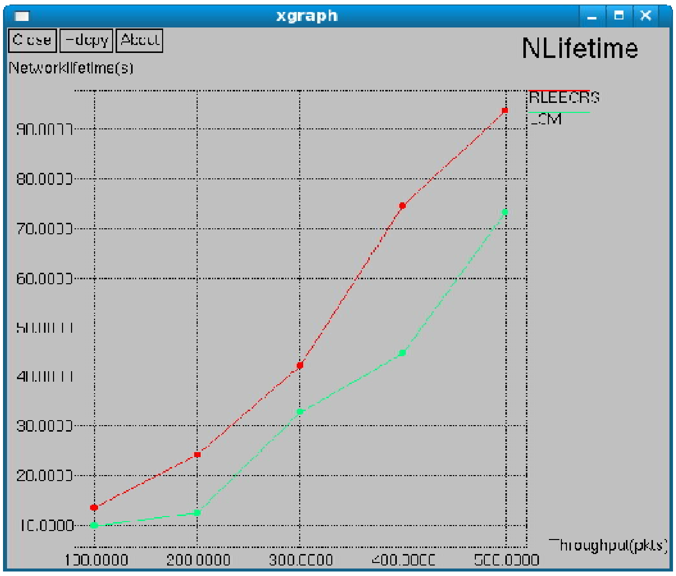

Fig. 4. Increasing the network lifetime

Fig. 5, presents the comparison of path reliability rate. It is clearly shown that the path reliability rate of RLEECRS is higher than the LCM.

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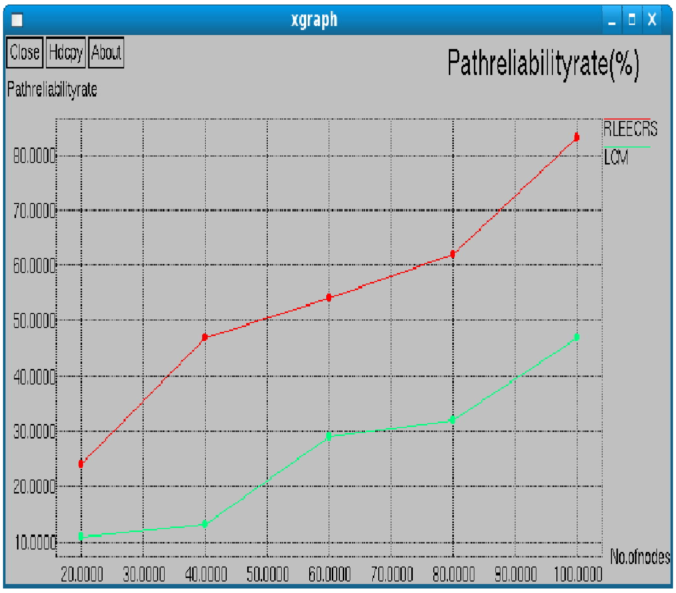

Fig. 5. Throughput Vs Path Reliability Rate

Figure 6 shows the results of Speed Vs End to end delay. From the results, we can see that RLEECRS scheme has slightly lower delay than the LCM scheme because of authentication routes.

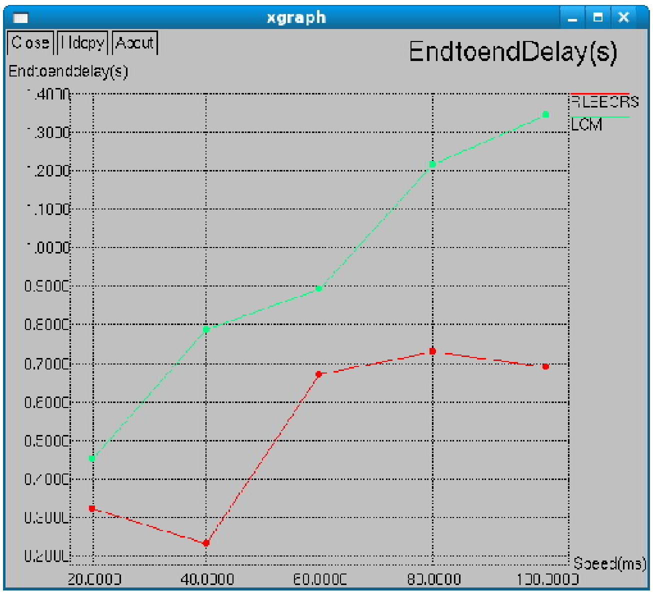

Fig. 6. Speed Vs End to end delay

Fig. 7, presents the comparison of Overhead while varying the mobility from 20 to 100. It is clearly shown that the overhead of RLEECRS is lower than the LCM.

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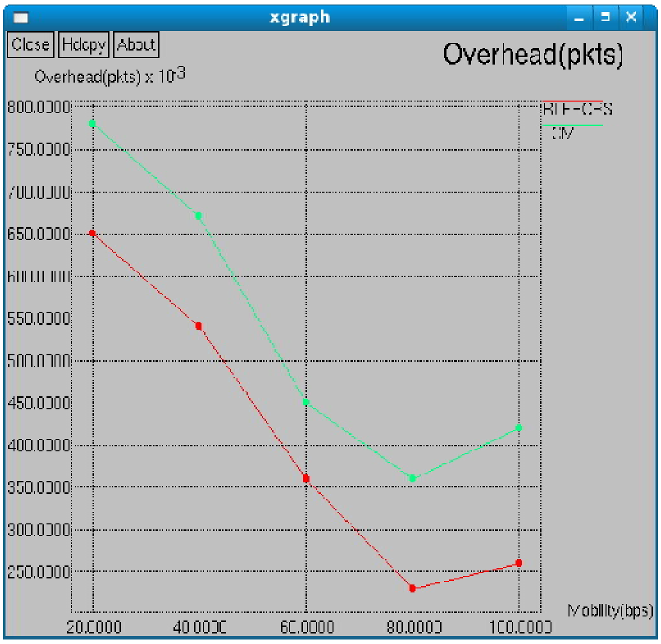

Fig. 7. Mobility Vs Delay

V. CONCLUSION

In WSNs, the best route is being determined by choosing efficient strategy to forward the data to the base station. Due to that, the node consumes more energy unnecessarily. In this paper, we have developed a reliable link based energy efficient cluster routing scheme which attains cluster routing, multipath establishment, and determination of path reliability and energy consumption to make a correct balance between path reliability, energy consumption and node lifetime to the sensor nodes. In the first two phases of the scheme, cluster routing and multipath route establishment are combined to achieve load balancing, minimum energy consumption and avoid network congestion. In third phase, minimum energy consumption model and path reliability calculation was proposed to achieve stable routing with minimum energy resources. It uses following factors called path delay, energy spent per packet during both transmission and reception to favor packet forwarding by maintaining high residual energy consumption for each node. We have demonstrated the energy estimation of each node. By simulation results we have shown that the RLEECRS achieves good throughput, high network lifetime, high residual energy while attaining low delay than the existing schemes LCM while varying the number of nodes, time, node throughput and mobility.

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