ELECTROSTATIC FIELD BASED RELIABLE ROUTING IN WIRELESS SENSOR NETWORKS USING VECTOR METHOD

Bappaditya Das[1], Utpal Biswas[2], Debabrata Sarddar[2]

[1]Department of Computer Science & Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India

[2]Computer Science & Engg., University of Kalyani, Kalyani, Nadia, West Bengal, India

ABSTRACT

Routing in Wireless Sensor Networks (WSN) is very challenging, due to several characteristics that distinguish them from existing communication and wireless ad-hoc networks. Data forwarding technique in Wireless Sensor Networks (WSN) is analogous with the motion of an electric charge in an electrostatic field. Shortest path routing does not guarantee to enhance the network lifetime and power-aware routing may increase the number of hops between the source and destination node. To trade-off between these two methods, our proposed vector projection approach gives the successful delivery of packets. From the definition of electromotive force (emf) of a battery, we are calculating the projection of attraction force along the line joining between source and destination node due to nodes positioned in the forward direction of propagation. Selecting the node as the next sink node having the capability of forwarding the maximum times of successful packet forwarding.

KEYWORDS: *Electromotive force, electrostatic field, power aware routing, vector approach.*

I. INTRODUCTION

WSN may be assumed to be a part of MANET which characterizes frequently varying topology and multi-hop communication. WSN constitutes several tiny, low powered, cheap sensors; these sensors in turn have components of sensing, data processing and wireless communication as its part. The nodes are scattered in a sensor field to communicate via self-organized channel of multi hop wireless communication network forwarding the gathered data towards one or multiple base stations connected to the network. Sensor networks have a versatile application field a few to state are battlefield surveillance, wildlife reserves, office buildings, biological detection[1][2]. Deployment area of WSN is mostly harsh environments where replacement of frequently dying out battery is a herculean task. The designing of sensor networks for optimal utilization of power to prolonging the lifetime of network is hence a challenging issue. Finding a path from source to destination for successful data transmission is called routing. In WSNs the network layer is mostly used to implement the routing of the incoming data. Generally in multi-hop networks the source node cannot transmit the data directly to the destination node. So, intermediate sensor nodes have to relay their packets. Depending on how the source finds a route to the destination MANET routing protocols can be classified into three categories: proactive, reactive and hybrid protocols.

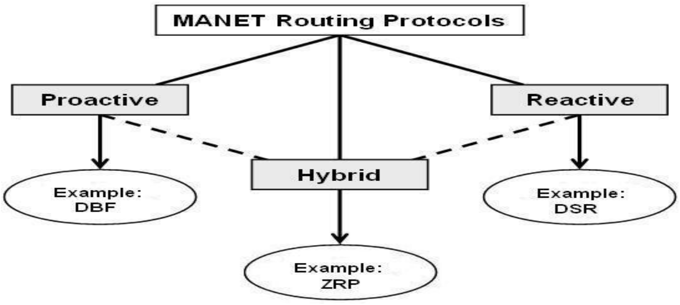

Figure 1: Routing Protocols in MANET [3]

Routing in WSNs is broadly classified into two types: Network structure based routing and Protocol operation based routing. Network structure based routing is further divided into flat-based routing, hierarchical-based routing and location-based routing whereas protocol operation based routing divided into multipath-based, query-based, QoS-based ,negotiation-based and coherent-based routing .

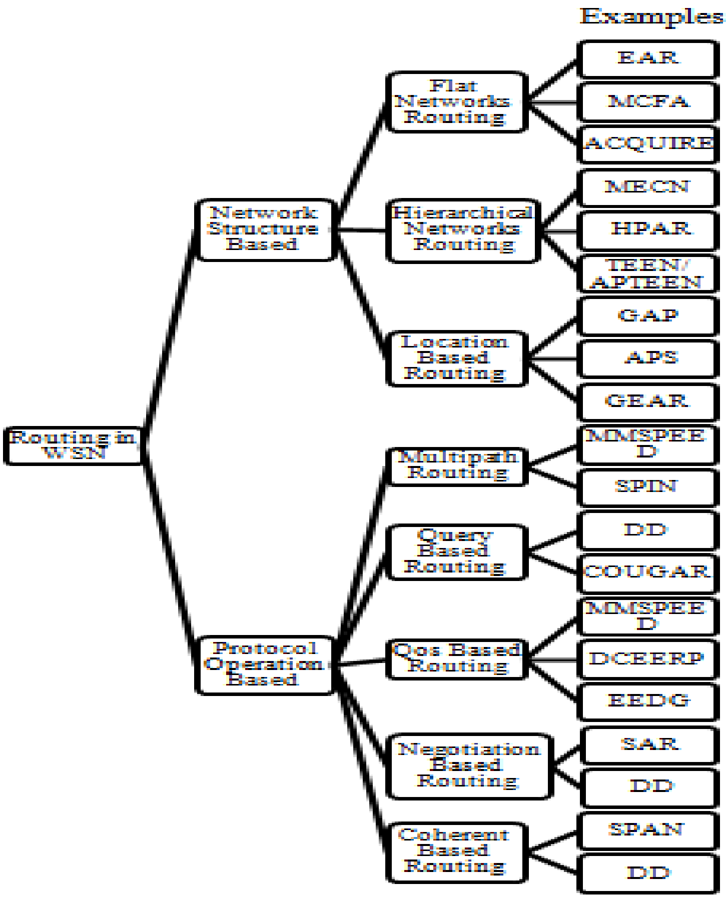

Figure 2: Routing Protocols in WSNs: A taxonomy

Flat Networks Routing: In a homogeneous dense network where it is impossible to assign a particular ID to each and every node flat based routing is needed. This leads to data-centric routing approach in which Base station sends query to a group of particular nodes in a region and waits for response. Energy Aware Routing (EAR [4]), Directed Diffusion (DD [5]), Minimum Cost Forwarding Algorithm (MCFA [6]), Active Query forwarding in sensor network (ACQUIRE [7]) are examples of flat based routing.

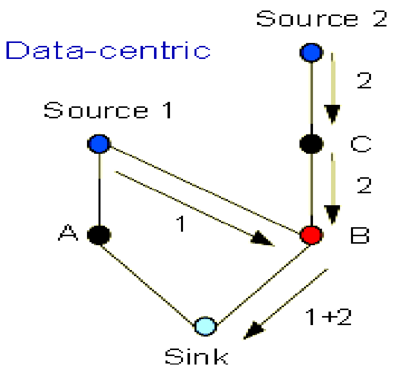

Figure 3: Flat Networks Routing

Hierarchical Networks Routing: Hierarchical-based routing, also known as cluster based routing is most effective when network scalability and efficient communication is needed. Hierarchical-based routing is energy efficient method in which nodes having high residual energy are randomly selected for processing and data forwarding while low energy nodes are used for sensing and sending information to the cluster heads.

Examples of hierarchical based routing protocols are: Hierarchical Power-Active Routing (HPAR[8]), Minimum energy communication network (MECN[9]), Threshold sensitive energy efficient sensor network protocol (TEEN[10]) etc.

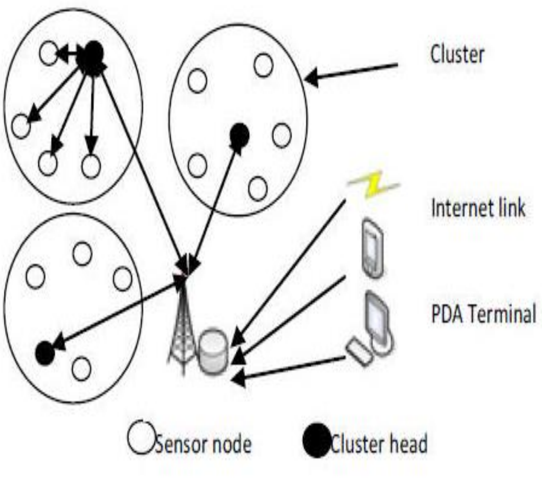

Figure 4: Hierarchical Networks Routing

Location Based Routing: In location based routing, sensor nodes deployed randomly in the deployment area and nodes are addressed by means of their location using virtual co-ordinate systems or by using GPS (Global Positioning System), if nodes are equipped with a low power GPS receiver.

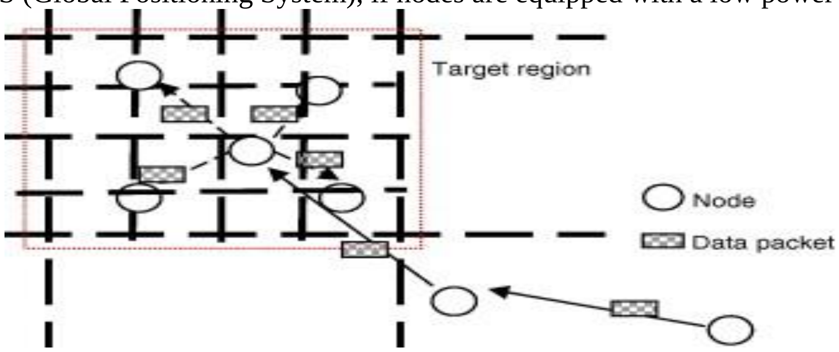

Figure 5: Grid Based Location Routing

In energy aware location based routing [11], authors proposed the scheme where nodes should go to sleep if there is no activity.

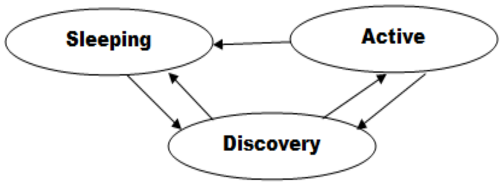

Figure 6: Relationship between the states of a node

Examples of location-based routing networks are: Geographic adaptive fidelity (GAF [11]), Ad-hoc positioning system (APS), Geographic and energy aware routing (GEAR [12]), Sequential assignment routing (SAR), Greedy other adaptive face routing (GOAFR), Geographic distance routing (GEDIR).

Multipath Routing: Here multiple paths are used rather than a single path to send the packet in order to enhance the network performance. Since frequency of using alternative paths due to failure of primary path between source and destination measures the resilience of the protocol so it is necessary to keep alive the alternative paths by sending messages periodically which in turns consume more energy. Multi path and Multi SPEED (MMSPEED), Sensor Protocols for Information via Negotiation (SPIN [13]) are the examples of multipath routing.

Query Based Routing: In this kind of routing, the destination node sends a query (generally written by high level language) for data from a node through the network and a node matches this query sends back the data to the query node.

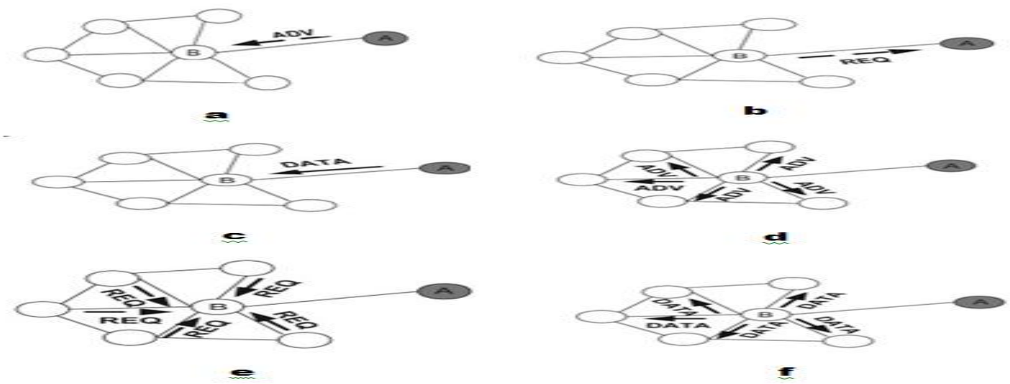

Figure 7: (a) Node A starts by advertising its data to node B. (b) Node B responds by sending request to node A. (c) Receiving the request node A sends data to B. (d) Node B sends advertise to all its neighbours. (e) Neighbours of B send requests to B. (f) Node B sends data to neighbours of B

Query based routing protocols are: Directed Diffusion (DD [14]), COUGAR [15].

QoS Based Routing: In QoS-based routing protocols, the network has to trade off between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc depending on the applications when delivering data to the BS. Examples of such routing are: Delay-Constrained, Energy-Efficient Routing Problem (DCEERP), Energy Efficient Data Gathering (EEDG), MMSPEED etc.

Negotiation Based Routing: This protocol is used to eliminate redundant data transmission by suppressing duplicate data through negotiation using high level data descriptors. Depending on the availability of the resources this protocol takes intelligent decisions either for communication or other actions. Examples of negotiation based routing are: Sequential assignment routing (SAR), Directed Diffusion (DD), SPIN etc.

Coherent Based Routing: Coherent and non coherent data processing based routing are two types of data processing techniques. In non-coherent data processing routing, after processing the raw data locally nodes send the processed data for further processing. The nodes that perform further processing are called the aggregators. In coherent routing, the data is forwarded to aggregators after minimum processing. This type of routing is used when energy efficient routing is required. SPAN [16] and DD are examples of this type of routing.

Till date many routing algorithms have been designed to enhance routing of data packet in terms of QoS and energy and bandwidth consumption. Previous works made the sensors flood the routing packets in all direction irrespective of the direction of the destination node consequently resulting in bandwidth wastage at a large scale and premature loss of battery life. This problem was solved by Location Aided Routing Protocols or Global Positioning System (GPS) to find the direction of propagation of the packets and avoiding backward propagation.

Clustered Wireless Sensor Network typically consists of several clusters of which each one comprises of a cluster head and member nodes located around the cluster head. Usually the node with maximal residual energy in the cluster is selected as the cluster head of that cluster. All the nodes are provided with a unique Id by the base station before being deployed. Sensors nodes of a cluster can communicate directly with their cluster head, which in turn integrates and transmits gathered information to the sink who stores the clusters and its members Id numbers. Sink may be viewed as a gateway to another network for data processing or storage centre or an access point for human interface to collect sensor readings.

The large difference in the distance of inter clustered and intra clustered transmission has induced the concept of relay transmission by selecting the intermediate node depending on the position of the source node and the destination node.

The rest of the paper is organized as follows: Section II is a brief review on the related work. In section III we present our proposed routing scheme. The simulation environment and experimental results are discussed in Section IV. Conclusions and future work are given in Section V and Section VI respectively.

II. RELATED WORK

Hierarchical Routing divides the network into regions and then route packets from one region to other. Regions are clustered as in [17] or may be in form of zones as in adhoc routing schemes. LEGION and PEGASIS are examples of this category. GPRS [18] and GEAR minimizes the energy consumed by considering both energy and distance.

The algorithm which utilizes location information to transmit information towards the geographic direction of destination via multi paths falls into the category of geographical routing. Here LAR intends to support topology based reactive routing to restrict the flooding to request zone from where nodes are selected to find the route between source and destination. ILAR is another location based routing algorithm which selects the closest neighbour to the base line as intermediate node.

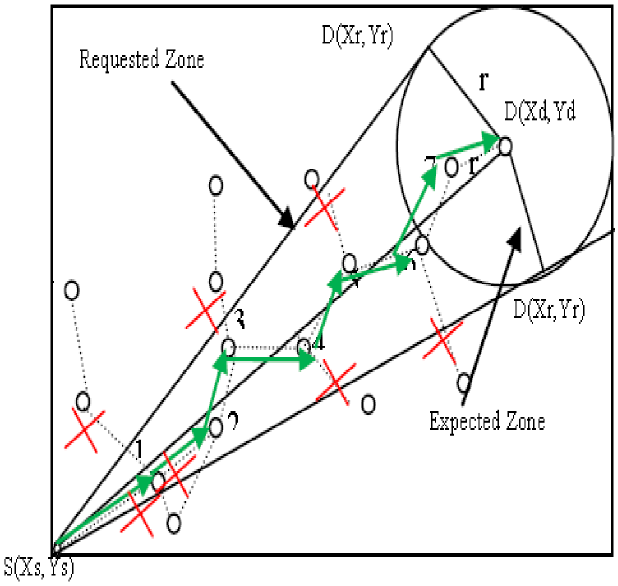

Figure 8: Route Discovery process of ELBPAR [19]

In [20,21] minimum energy path from source to destination is chosen which leads to loss of battery of nodes along the path rendering other nodes of the network useless even if they have sufficient power to become the member of alternative path.

Direct transmission of data packet between the CH and the sink node causes the far off nodes to die off earlier. As a solution to this problem, author of [22] suggests successful data transmission by using cooperative transmission scheme and through proper synchronization of sleep and wake mode of the nodes maximizing the networks lifetime. Flooding of packets to the neighbors without considering energy and distance parameters and lacking the concept of CH is termed as flat routing [23],[24].In most routing strategy shortest paths are computed in order to minimize the hop count or delay. Path through the nodes having maximum residual energy guarantees successful transmission of data in a longer route. Singh et al. [25] propose several algorithms for power aware routing in MANET. This routing protocol [25] addresses the issue of energy-critical nodes by minimizing the sum of function, f(A) proposed by the authors, for nodes on the path.In [26] and [27] proposed several localized demand based routing algorithms to prolong the networks lifetime by minimizing the consumption of total energy per packet.

Communication costs significantly more than processing cost. Pottie and Kaiser [28] proposed a strategy to trade-offs between data processing and wireless communication. In [29], authors suggested the local data processing strategy to minimize power consumption in a multihop wireless sensor network. Recently many researchers relate the problems of WSN with the classical physics and solve the problems using mathematical physics. The problem of optimal design and operations of heavily dense WSN was mapped to electric charge distribution in electrostatics by S.Toumpis and other researchers [30]. M.Kalantari and M.Shayman [31, 32] mapped the routing problem in Ad Hoc networks with the electrostatic field and find a route of every sensor by solving their proposed series of Partial Differential Equations (PDEs).They extended their works [33] for multi-sink sensor networks using the same analogy. In case of mobile sinks, mostly considering on residual energy the authors of [34] proposed the process of deployment of multiple sinks in sensor networks for building an energy efficient network. Velocity of light in a media depends on the refractive index of the media. In [35, 36] authors map the routing problem through dense network as the propagation of light in some media with different refractive index. In [37], authors proposed a simple Magnetic Diffusion (MD) mechanism based on magnetic field. In this method, the sink and data are modelled as magnet and metallic nails respectively. Data can be forwarded to the sink according to the magnetic charge of every node. For timely delivery data, achieve high data reliability and energy efficiently performance of MD is quite well but it could not be useful the networks resources uniformly. In [38], the process of data forwarding in sensor networks abstracting as gravitational field is analogy to electric charge moving in electrostatic field. In this gravitational field, sink node has gravitational to the data and data can flow to sink under this gravitational. Based on this gravitational field, a routing method with lower time and space complexity that can be applicable well in Multi-Sink sensor networks is proposed in this paper.

III. PROPOSED WORK

In [39], [40] routing algorithms for networks with randomly deployed sensors grouped into equally sized and equally spaced square grids in a two dimensional plane. Some of the pre assumptions for our system model are, all the nodes of requested zone are aware of its position through GPS technique. The nodes are assumed to be static during the data gathering phase.

The WSN is assumed to be a homogeneous network i.e. all the nodes are having same computational power, storage capacity and communication range. The node that will be selected must have residual energy greater than threshold energy value.

To transmit a l-bit message a distance d meters the radio expends:

$$E_{Tx} = lE_{elect} + le_{fs}d^2 \quad for \quad 0 \le d \le d_{crossover}$$

$$E_{Tx} = lE_{elect} + le_{mp}d^4 \quad for \quad d > d_{crossover}$$

Where *efs* and *emp* is the energy consumed by amplifier for short and long distance respectively. *Eelect* is the electrical transmission/reception energy and *dcrossover* is the limit distance for it parameters must be changed. The energy expended in receiving an *l*-bit message is given by

$$E_{Rx} = l*E_{elect}$$

From electromagnetism of physics we know that electric charge can generate electrostatic filed, and it has the power to influence other charges which are placed in this filed. A positive charge moves toward to the negative charge under the force of attraction in an electrostatic field which was generated due to negative charge. Consider the data flows from the sensor to the sink by multi-hop way in the sensor networks; it is analogy to the charges interaction and moving in the electrostatic field. By this analogy, we make the following abstracting:

The data that monitored by sensors is abstracted by positive charge with appropriate magnitude; the sink is modelled by negative charge with appropriate magnitude, and sink has attraction to the data. Each of eight neighbours of source node can be considered as sink node. Since Electromotive force is not really a force, but a measure of how much work would be done by moving an electric charge. So sensor node having more battery power has the capability of doing more work. Dividing work done by the distance represents magnitude of force. Using this analogy of mechanics, here dividing the residual energy of node by the distance between that node from the source node we measure the force of attraction. Dividing this attraction force by the distance between source and destination gives the factor which will indicate the number of successful transmission of data.

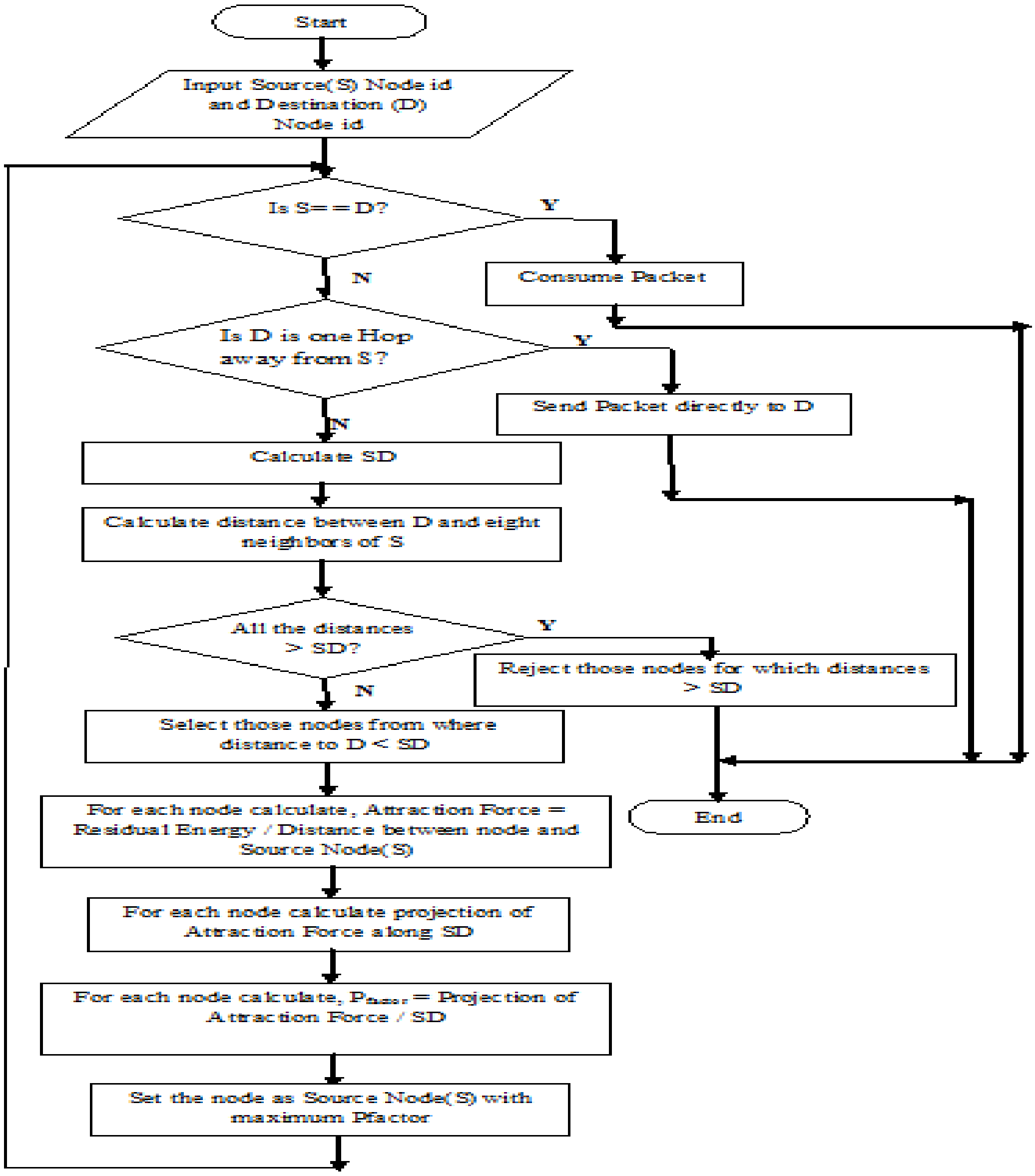

Figure 9: Flowchart of proposed algorithm

Suppose a packet will be delivered from source node S of co-ordinate (xs,ys) to destination node D of co-ordinate (xd,yd) . S has the 8 neighbours node A,B,C,Q,G,K and P of co-ordinate (xs+1,ys), (xs+1,ys+1),(xs,ys+1),(xs-1,ys+1),(xs-1,ys),(xs-1,ys-1),(xs,ys-1) and (xs+1,ys-1)respectively.

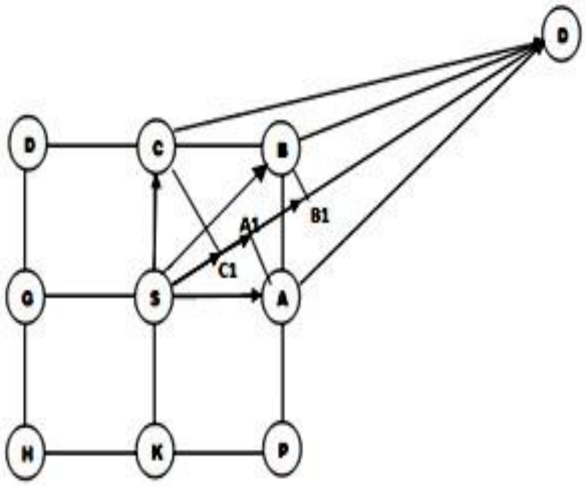

Figure 10: Diagram of selecting suitable neighbour using proposed method

Let E_j the residual energy of j node and $d_{i,j}$ is the Euclidian distance between node i and node j. Node S can forward the packet to its one of 8 neighbours that will become as next sink node by considering the residual energy of neighbour's node as well the distance covered by that along the straight line joining between S and D.

Calculate $d_{S,D}$ and slope(m) of the line SD using the formula, m = (yd- ys)/(xd-xs).

$F_{S,J} = E_J / d_{S,J}$

Calculate, distance between D and all neighbours of S. Find distance between S and all neighbours of S.

$d_{D,J}$ for $\forall J = \{A, B, C, Q, G, H, K, P\}$

$d_{S,J}$ for $\forall J = \{A, B, C, Q, G, H, K, P\}$

For $\forall J = \{A, B, C, Q, G, H, K, P\}$

If($d_{S,J} \le d_{S,D}$)

{

Calculate attraction force on node N ($N \in \{A, B, C, Q, G, H, P\}$) due to residual energy of node N using the formula, $\left|\vec{F}_{N,S}\right| = \frac{E_N}{d_{S,N}}$

Draw perpendicular on $\overline{SD}$ from node N. Find out the perpendicular distance,

$$d_{N,N1} = \frac{|y_N - mx_N - c|}{\left|\sqrt{1+m^2}\right|}$$

Find out the component of $\vec{F}_{N,S}$ along $\overrightarrow{SD}$ using, $\left|\vec{F}_{N,S}\right| \cos\theta_n = \frac{\overline{SN_1}}{\overline{NN_1}}$

Calculate $P_{(factor)_N} = \frac{\left|\vec{F}_{N,S}\right| \cos\theta_n}{d_{S,D}}$

}

Choose the node as sink node having maximum $P_{(factor)}$ and set as source node for next iteration.

IV. Simulation Result

In order to evaluate the performance the proposed algorithm and to show its competence we present simulations using MATLAB using the following simulation parameters:

Table 1: Simulation parameters

Number of nodes	100
Deployment area	Square
Network type	Homogeneous
Network Topology	Grid
Node mobility	Stationary
MAC Protocol	IEEE 802.11
Propagation model	Two Ray Ground
Node distribution	Uniform
Minimum Initial Energy	1J
Eelect	50 nJ/bit/m2
efs	10 pJ/bit/m4
εmp	0.0013 pJ/bit/m4

Here we assume that every node have the sufficient energy to send the packet to its neighbour. The slope of the straight line joining source node and destination node can be zero, infinite and a finite value. All the cases have been considered here.

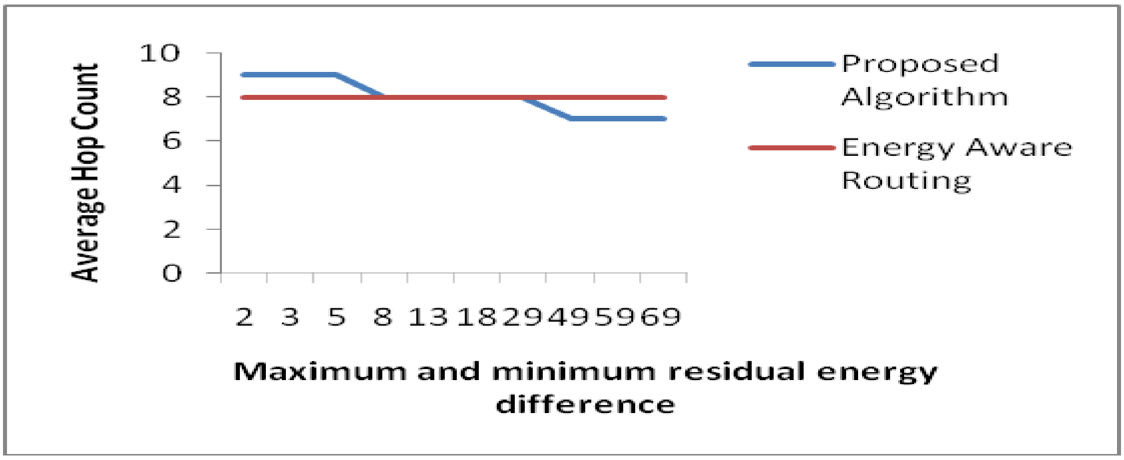

Figure 11: Average Hop Count Vs Maximum and minimum residual energy

In Figure 11, we have evaluated average hop count against the energy difference between the maximum energy and minimum energy and compared with existing energy aware routing algorithm where packet forwarded through the intermediate nodes having maximum residual energy.

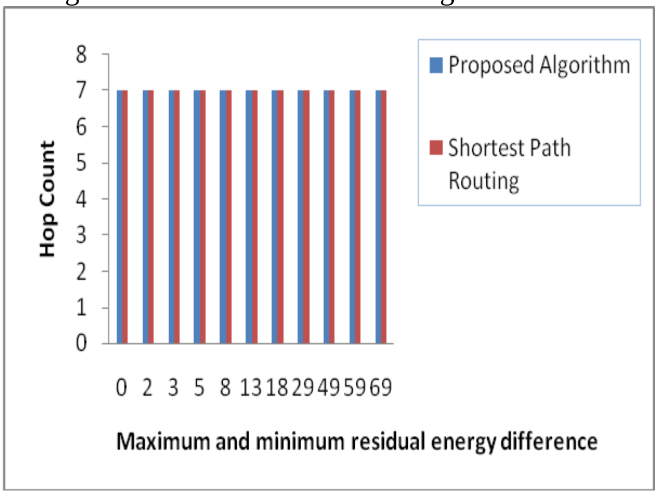

Figure 12: Hop Count Vs Maximum and minimum residual energy difference

In Figure 12, we have evaluated hop count against the energy difference between the maximum energy and minimum energy and compared with existing shortest path routing algorithm where packet forwarded from source to destination node via the shortest path.

V. CONCLUSIONS

In this paper, we have proposed a routing algorithm for reliable data transmission based on electrostatic field using vector method. Here we evaluated the performance of our proposed algorithm and also compared with existing routing algorithm. In case of data transmission when the slope between source node and destination node is finite but not equal to zero and the energy differences between the maximum and minimum energy is large enough the experimental results show that our algorithm performs better. In case of data transmission when the slope between source node and destination node is zero or infinite then it traverses same number of hops compared with shortest path. During the simulations it is observed that our algorithm follows the different path for sending a packet to the destination node but the total number of hops remain same.

VI. FUTURE WORK

There are several future works we would like to improve our algorithm by considering the balanced load distribution as well as the mobility of nodes. In future we would also like to improve our algorithm in case of random deployment of the nodes.

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AUTHORS

Bappaditya Das, Assistant Professor in the Department of Computer Science & Engineering of Dr.B.C.Roy Engineering College, Durgapur, West Bengal, INDIA. He had done his M.Tech in Computer Science & Engineering from University of Calcutta. He passed B.Tech in Computer Science & Engineering from University of Calcutta. He passed B.Sc in Physics Hons. from University of Calcutta. He is currently working toward the Ph.D. degree at University of Kalyani. His area of interest is on Wireless Sensor Network, Mobile Computing, Algorithms, Cryptography etc.

Debabrata Sarddar, Assistant Professor in the Department of Computer Science and Engineering, University of Kalyani, Kalyani, Nadia, West Bengal, INDIA. He has done PhD at Jadavpur University. He completed his M.Tech in Computer Science & Engineering from DAVV, Indore in 2006, and his B.E in Computer Science & Engineering from NIT, Durgapur in 2001. He has published more than 75 research papers in different journals and conferences. His research interest includes wireless and mobile system and WSN.

Utpal Biswas, Associate Professor in the Department of Computer Science and Engineering University of Kalyani, Kalyani, West Bengal, INDIA . He received his B.E, M.E. and PhD degrees in Computer Science and Engineering from Jadavpur University in 1993, 2001 and 2008 respectively. He served as a faculty member in NIT, Durgapur, INDIA in the Department of Computer Science and Engineering from 1994 to 2001. He is a co-author of about 90 research articles in different journals, book chapters and conferences. His research interests include Optical Communications, Ad-Hoc and Mobile Communications, Sensor Networks, Semantic Web Services, E-Governance etc.