ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

IJIRSET

International Journal of Innovative Research in Science, Engineering and Technology

Volume 3, Special Issue 3, March 2014

2014 International Conference on Innovations in Engineering and Technology (ICIET'14)
On 21st & 22nd March Organized by

K.L.N. College of Engineering, Madurai, Tamil Nadu, India

The Energy Conservation via Geographic Forwarding in K-Covered WSNs

S.Rajamani , Nandagopal

Dept. of Communication System, M.Kumarasamy College of Engineering (Autonomous), Thalavapalayam, Karur, India.

Dept. of Electronics and Communication Engineering,M.Kumarasamy College of Engineering (Autonomous), Thalavapalayam, Karur, India.

***ABSTRACT*—**Wireless sensor Networks (WSNs) has made an important look in emerging technologies based on its usage in specific application. Effectiveness of WSNs is its coverage and connectivity. Proper coverage and connectivity maintenance enhances low availability of nodes for tracking, data collection, aggregation, information transfer in dense multi-hop networks. To perform these, energy has to be conserved in great amount. To support coverage and connectivity we analyze with $k \geq 3$ (k=active sensors) using a deterministic approach so the network self-configures to meet diverse requirements with the environment and different applications. The main challenge in the design of WSNs is the limited battery power of the sensors. This paper deals with our framework, called Cover-Sense-Inform (CSI), includes randomized centralized and distributed protocols for connected *k*-coverage along with geographic forwarding protocols in duty-cycled, *k*-covered WSNs. Simulation results show that our protocols select a minimum number of sensor nodes, thus improving energy savings. We propose deterministic geographic forwarding protocols for duty-cycling *k*-covered wireless sensor networks (WSNs) with different levels of data aggregation. Simulation results estimate that CSI yields significant energy savings while guaranteeing high data delivery ratio and also specifies that our solution yields uniform energy consumption of all the sensors, thus extending the lifetime of networks.

KEYWORDS— Wireless Sensor Networks, Coverage, Connectivity, Aggregation, Scheduling, Clustering, Geographic forwarding

I.INTRODUCTION

Wireless Sensor Networks (WSNs) [3] has become an active and increasing interest in the field of research recently. Its existence has been improved day by day as it was utilized in many applications such as remote environment monitoring in military, target tracking to detect movement, temperature changes, precipitation, sound, vibration, light, humidity etc, surveillance, natural calamity relief, biomedical health care monitoring of patient, riskful environment exploration, Earthquake sensing and scientific applications refer Fig.1. The nodes are characterized by small size with limited energy usually supplied by a battery. They communicate via built-in RF radio antennae. There are two types of WSNs: structured and unstructured [3]. Structured WSNs have nodes pre-determined to be placed at fixed location. Unstructured WSNs have nodes randomly placed in the field. Resource constraints include a limited quantity of energy, short connectivity range, less bandwidth requirement, low memory unit, limited processing and storage in each node. The size, topology, deployment of nodes depend on the environment. Services rendered to these constraints have been discussed later in proceeding sections.

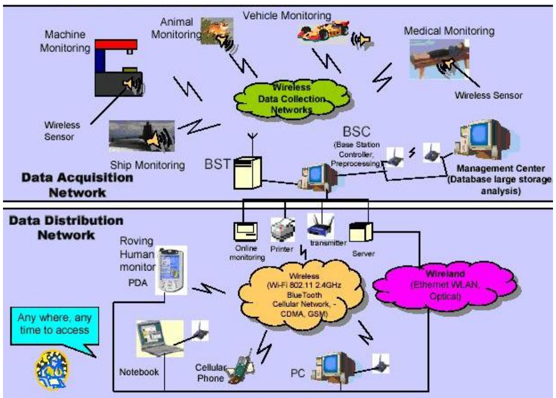

Fig.1Wireless Sensor Networks (WSNs)

For the nodes to have better sensing and communication range it needs proper coverage and connectivity [13]. Coverage is defined as the quality of service that how well sensor network will monitor the field of interest. Most researchers focus on a single deployment model but there are papers that attempt to develop a more. Connectivity [11] can be defined as the ability of the sensor nodes to reach the data sink.

Almost all applications of sensor networks require the flow of sensed data from multiple regions (sources) to a particular sink. It is not possible to build a global addressing scheme for the deployment of sheer number of sensor nodes. Generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of an unusual happening. Such redundant data needs to be utilized fully by the routing protocols to improve energy and bandwidth utilization. Routing protocols [4] can be of data centric, hierarchical or location based for the problem of redundant data transmission.

A. Motivations

It is important to minimize the amount of data transmission so that the average sensor lifetime and the overall bandwidth utilization are improved. Data aggregation is the process of abstracting and combining sensor data in order to reduce the amount of data transmission in the network. Data aggregation protocols aim to combine and summarize data packets of several sensor nodes so that amount of data transmission is reduced. Designing protocols for WSN's faces a challenging problem, namely energy conservation due to constrained (limited) battery power (energy) of sensors. Duty cycling is the best approach to save energy of sensors by making it ON or OFF according to some sleep-wake up scheduling protocol. Geographic forwarding is an energy efficient practical scheme for WSN's in which sensors need only to maintain local knowledge on geographic locations of one-hop neighbors', to select their next forwarders to progress data towards destination rather than maintaining global and detailed information. Data collected should be forwarded to central gathering point known as sink through active sensors.

B. Problem statement and challenges

This paper offers joint protocol development, where K-coverage, duty cycling and geographic forwarding (routing) are discussed in a unified framework. We focus on geographic forwarding in a duty cycled $k \geq 3$ active sensors where all active sensors are connected. Geographic forwarding in a CWSNk faces three major challenges.1.) How to determine the no. of active sensors required to fully k-cover a field. For results of 1-coverage, all those intersection points between the boundaries of sensing ranges of the sensors and boundaries of the field are k-covered. If two sensing ranges intersect, 1 more is needed to cover their intersection point. For 3-covered, a point in a field coincides with intersection point. Our approach is yielding a minimum no. of sensors.2.) How to design minimum energy duty cycling protocol for CWSNk that deploys minimum no. of active sensors, so utilization of energy is reduced. Our goal is to increase the lifetime of sensors so as to increase the network life time.3.) How to design energy-efficient GFP combining with duty cycled CWSNk (joint protocol) with specific requirements in terms of data aggregation. 4.) How to reduce the k-active sensors to forward the data towards sink for the efficient packet delivery ratio.

The rest of this paper is structured as follows: Section II reviews related work on efficient energy conservation schemes. Section III describes the Existing model. Section IV presents some simulation results and performance analysis. Section V proposes less usage of nodes. Finally, Section VI concludes the paper.

II.RELATED WORK

A variety of configuration protocols for coverage and connectivity[12] in wireless sensor networks have been proposed in the literature with a goal to extend the network lifetime.

G. Xing, X. Wang, Y. Zhang, C. Lu, R. Pless, and C. Gill proposed CCP [5] which is a decentralized protocol to provide a specific degree of coverage. CCP can change the degree of coverage when requested by the application. In CCP, a node can be in one of three states: inactive (sleep), active, and listen (watch). In the inactive state, the node turns off its radio until the sleep timer finishes its count, and then it reaches the listen state. In the listen state, the node collects hello messages from its neighbor's and executes the Ks-coverage eligibility algorithm. The Ks coverage eligibility algorithm determines whether a node is eligible to switch states. If every location within a node's coverage range is not Ks-covered by other active nodes, the node will be eligible to become active, else it will go back to sleep. In active mode, the node periodically updates its sensing neighbor table and executes the Ks-coverage eligibility algorithm to determine if it will remain active. CCP maintains a table of known sensing neighbors based on the beacon (Hello messages) that it receives from its communication neighbors. When $Rc \geq 2Rs$, HELLO messages from each node only needs to include its own location.

G. Xing, X. Wang, Y. Zhang, C. Lu, R. Pless, and C. Gill proposed SPAN [5] which is also a de-centralized co-ordination protocol that conserves energy by turning off unnecessary nodes while maintaining a communication background composed of active nodes. CCP does not guarantee connectivity when $Rc<2Rs$. The communication backbone maintains the topology of the network such that all active nodes are connected through the backbone and all inactive nodes are directly connected to at least one active node. The table contains location of one hop neighbors and makes local decisions on whether to sleep or stay awake as a coordinator and participate in the communication background. In SPAN, Hello message includes the node location coordinates and IDs of neighboring coordinators. SPAN is possible when $Rc \leq 2Rs$ where some nodes do not known the location of sensing neighbors. We integrate CCP [6] with a representative connectivity maintenance protocol (SPAN) to provide both coverage and connectivity guarantees when the ratio of Rc and Rs range is lower than two.

Proposed a greedy geographic routing protocol, called Bounded Voronoi Greedy Forwarding (BVGF) [8]. The nodes eligible to act as the next hops are the ones whose Voronoi regions are traversed by the segment line joining the source and destination node. The BVGF protocol selects the next hop as its neighbor that has the shortest Euclidean distance to the destination among all eligible neighbors. This protocol does not help the sensors deplete their battery power uniformly. Each sensor has only one next hop to forward its data towards their sink [4]. Therefore, any data scattered or spreading (disseminated) path between a source sensor and the sink will always have the same chain of next hops, which will severely suffer from battery power depletion. The major problem of this algorithm is that it requires the construction of the Voronoi diagram and the Delaunay triangulation of all the wireless nodes. This strategy is very expensive in distributed environments, such as sensor networks.

Biswas and Morris proposed an integrated routing and MAC protocol, called ExOR [7], to enhance throughput in multi-hop wireless networks, where a source sends a group of packets destined to the same destination. ExOR is also an opportunistic routing protocol that determines the next forwarder of a packet after the transmission of the packet. The node closest to the destination among all the candidate forwarders that receive the packet is selected in each hop.

However, these methods cannot enhance the effective coverage problem with limited usage of sensor which should be considered as a main factor.

III. EXISTING MODEL

In this section, we present our first potential field based solution for geographic forwarding on a duty-cycled *k*-covered wireless sensor network, called Geographic Forwarding through Fish Bladders (GEFIB), where data is forwarded through fish bladders (or lenses). Precisely, we discuss three geographic forwarding protocols with different levels of data aggregation.

A. *Attractive force-based modeling approach*

Sensors viewed as particles are subjected to virtual attractive forces due to remaining energy in the sensors and their geographic locations shown in Fig.2 [10]. Sensors with highest remaining energy act as relays to avoid energy holes (i.e., regions whose sensors depleted their energy) that disconnect the network. Sensors prefer closer ones to act as relays and forward data over short distances [17]. Energy location based force (*Fel*) (called attractive force) exerted by active sensor and defined as gradient of different scalar potential field called energy location based potential field (*Uel*) i.e.) $F_{el} = -\nabla U_{el}$. The idea of attractive force is symmetric. If active sensor *Si* exerts force on another active sensor *Sj*, then *Sj* also exerts force on *Si* with the same magnitude. Therefore modeling the resultant force between *Si* and *Sj* is from electromagnetism theory. By Coulomb's law [21],

$$F(i,j) = -\nabla U(i,j) = \frac{1}{4\pi\varepsilon_0}\,\frac{|q_i||q_j|}{d^2(i,j)},$$

where, F *(i, j)* is the electrostatic force between two points which depends on $|q_i||q_j|$, the magnitude of electric charges of two sensors *Si* and *Sj* , ε_0 is the permittivity of free space and d^2*(i,j)* which is the Euclidean distance between two points (sensors)*Si* and *Sj*. In our model, the sensor's charge is its remaining energy (*Erem(i)* and *Erem(j)*) of two sensors. The attractive force is computed as,

$$F_{el}(i,j) = -\nabla U_{el}(i,j) = \frac{1}{4\pi\varepsilon}\,\frac{E_{rem}(i)E_{rem}(j)}{d^{\alpha}(i,j)}$$

where, *Fel(i,j)* is the energy location based attractive force, $\varepsilon \in \{\varepsilon_{fs}, \varepsilon_{fs}\}$ is the dependency of permittivity due to transmitter amplifier[17] in the free space (ε_{fs}) model $(\alpha = 2)$ or multipath (ε_{mp}) model $(2 < \alpha \leq 4)$ where, α is the path loss exponent.The magnitude of attractive force *Fel(i,j)* that a sensor *Si* exerts on its sensing neighbor *Sj* is proportional to the product of remaining energy and inversely proportional to the Euclidean distance d^2*(i,j)* between them. *Fel(i,j)* is dealt with type of free space versus multipath model being used. Similarly, resultant force exerted by *Si* on a set of sensors(*S*) is given by,

$$F_{el}(i,S) = \sum_{s_j \in S} F_{el}(i,j) = -\sum_{s_j \in S} \nabla U_{el}(i,j)$$

Next we will see GFP for a duty cycled CWSN*k*.

B. *Attractive force-based data forwarding without aggregation*

This is done based on artificial potential fields (GeRaF-Geographic Random Forwarding)[14]. The best relay of sensor (*Si*) is a sensing neighbors (*Sl*) between *Si* and sink such that *Fel(i,l)* is the maximum overall resultant forces exerted by *Si* on its sensing neighbors(*Sl*).i.e.,)

$$F_{el}(i,l) = \max\{F_{el}(i,j) : s_j \in SN(s_i)\}.$$

Selecting the best relay means, it selects the neighboring sensor *Sl* which is experiencing the greatest or maximum force from *Si*.$\max\{F_{el}(i,j) : s_j \in SN(s_i)\}$ is the maximum force exerted by *Si* on its neighbor, would be selected from *Sl* and the data is forwarded to the sink. *Sj* is the neighbor which belongs to *Sl*.$s_j \in SN(s_i)\}$ implies that *Sj* belongs to sets of sensors neighbor to *Si*.

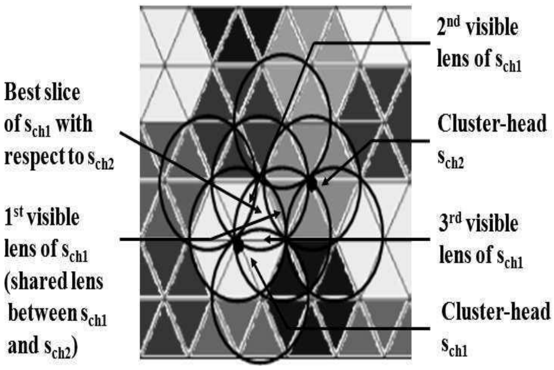

Fig.2 Communication between adjacent cluster-heads

C. *Attractive force-based data forwarding with aggregation*

In this section, we present two geographic forwarding protocols with data aggregation on a duty cycled *k*-covered wireless sensor network. All data originated from sensors in a cluster are received by their corresponding cluster-head, which aggregates them with its own data into only one single data. Precisely, each sensor sends its data directly to its cluster-head, where data is aggregated. We distinguish two types of aggregation. In the first scenario, referred to as local data aggregation, aggregation occurs only within clusters and all data aggregated by cluster-heads are forwarded to the sink without further aggregation. Thus, the sink receives data from each cluster-head in each round. In the second scenario, referred to as global data aggregation, the sink receives only one data packet in each round that represents the aggregation of all data aggregated by cluster heads.

D. Local aggregated data forwarding (LAD)

Each sensor sends data to its cluster heads without relaying via intermediate sensor. Cluster heads (*Si*) after receiving data, aggregates with its own data and forward the result called Locally Aggregated Data(LAD)[1] towards sink.Sink receives as many LAD packets as cluster heads shown in Fig.3. When one cluster head transmits LAD packets to another cluster head, then this cluster head forward that received LAD packets without any update.Precisely cluster head finds the best slice (with respect to sink),then chooses the best lens (in terms of attractive force out of the 3 visible lens).From this lens it selects the best relay (based on potential field based force) and forwards data to the nearest cluster head.This forwarding of data using relays takes place via fish bladders (or lenses).

E. Global aggregated data forwarding (GAD)

In each round, sink receives only one aggregated data packet called GAD[1] (averaging of LAD generated by cluster heads) at any time.Precisely each cluster head avgs. its own data with the averaged data it has received from the other cluster head and forwards to another cluster head. Each cluster acts as a relay on behalf of other cluster heads until GAD packet reaches the sink. Forwarding of GAD should be done by the cluster heads only.This is costlier for cluster heads as energy spent for transmission is proportional to the transmission distance.

To enable data aggrregation at cluster heads DAT(Data Agggregation Tree) is to be constructed.In Data Agggregation Tree (DAT) Cluster heads should be as close as possible.Open ring which consists of two aggregation initiator (initiates data aggregation),one ring aggregator(located somewhere on open ring responsible for the aggregated data on its ring).Each ring has ring_id by which cluster head forward their aggregated data towards their ring aggregator and each cluster head in the same ring has the same ring_id. Two aggregation initiators are adjacent to each other and in that one aggregation initiator act as a aggregation proxy which selects the aggregation initiator for the next ring and advertise the value of ring_id to that ring's cluster heads in the clockwise direction, while aggregation initiator did it in anticlockwise direction.

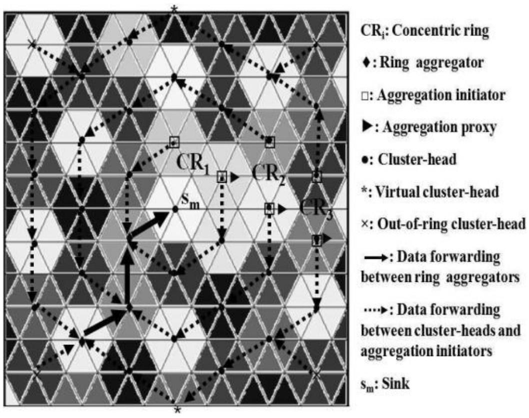

Fig.3 Data forwarding on a random data aggregation tree

IV. Simulation Results And Performance Analysis

The following are the simulation results of the existing model. This project is run on the NS-2(Network Simulator) with C++ as its coding language background. There are various parameters which are compared and analyzed to identify its performance in WSNs. The main goal is to increase the PDR, decrease the delay, increase the throughput and to increase the lifetime of sensors. Fig 4.1-4.8 is dealing with it.

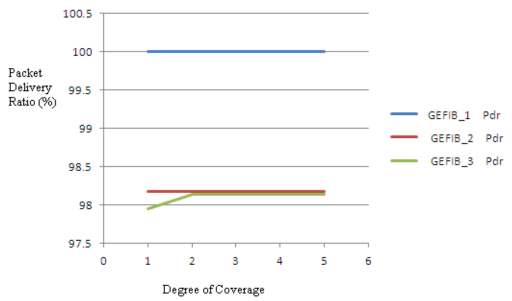

Fig.4.1 Degree of coverage Vs PDR

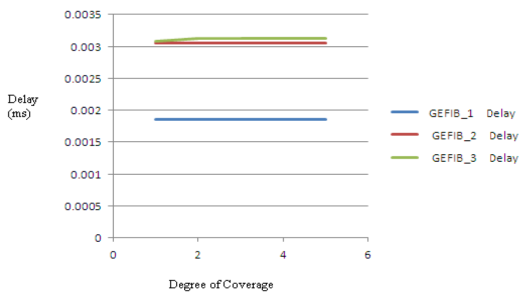

Fig.4.2 Degree of coverage Vs Delay

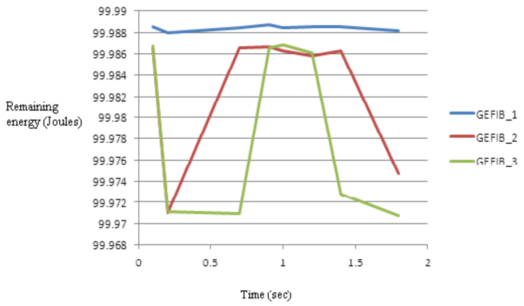

Fig.4.3 Time Vs Remaining energy

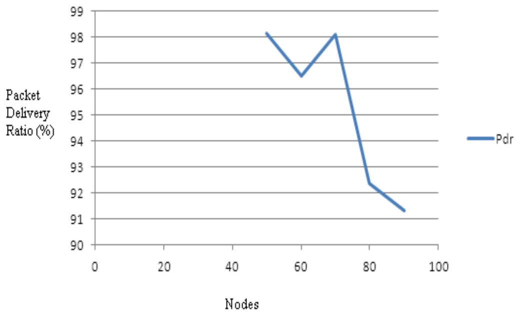

Fig.4.4 Node Vs PDR

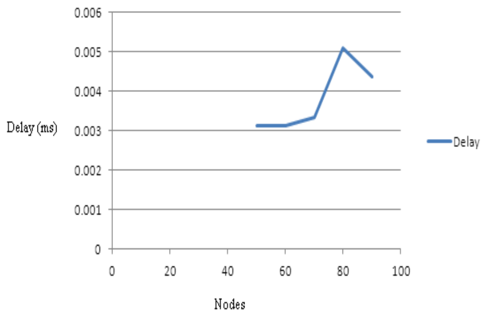

Fig.4.5 Node Vs Delay

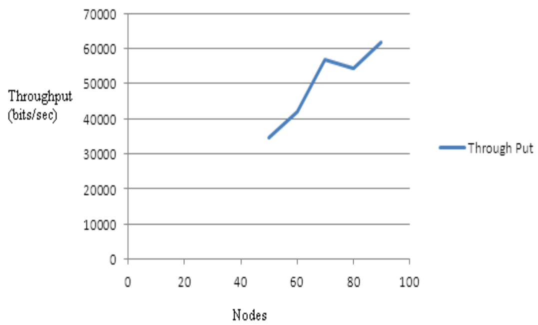

Fig.4.6 Node Vs Throughput

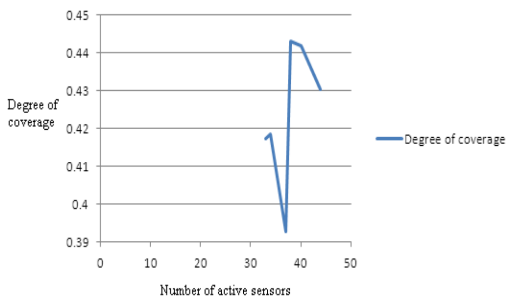

Fig.4.7 Number of active sensors Vs Degree of Coverage

Fig.4.1 depicts the gradual increase in PDR as the degree of coverage for GEFIB-3 increases and performs constant value.GEFIB-3 has low PDR when compared to GEFIB-1.This is because, when aggregating[19] the sensed data it takes time to reach the sink as it follows the Globally Aggregated Data (GAD) while GEFIB-1 forwards its sensed data directly without aggregation as it uses potential fields for selection of neighboring nodes to forward data towards sink.So PDR for GEFIB-I is high. Fig.4.2 shows that there is a high delay in case of GEFIB-3 as degree of coverage increases compared to GEFIB-2 and 1.This is because as PDR of receiving the packets is low for GEFIB-3,travelling time period taken by the packets is automatically high.Fig.4.3 explains about the gradual depletion of energy as the time increases.GEFIB-1 offers a long time service than GEFIB-2 and 3.For GEFIB-3, at starting it has high energy and as the time increases energy decreases as the sensor gets into active mode[2] and then increases as the sensor is brought back to sleep mode.The same modes are followed in GEFIB-2 but the decrease in their remaining energy is less than GEFIB-3(uses GAD) because it uses Locally Aggregated Data (LAD).Fig.4.4 predicts the fluctuation as the PDR decreases when number of nodes increases so gradually the delay increases.Fig.4.5 specifies increase in delay of receiving the packets as the nodes increases.Overall there is an increase in the throughput as the no of nodes increases in Fig 4.6. Fig.4.7 explains the sudden increase in degree of coverage from decreasing as the number of active sensors increases.This is because, the number of nodes which is in active mode for sensing is less at the starting time and number of active sensors is more as the time prolongs.So the Degree of Coverage is high for more number of sensors and that it transmits fast via more number of active sensors towards the sink. Overall the energy has been conserved as much as possible in a considerable amount.

The problem of routing on duty cycled WSNs has received little attention in the literature survey. In particular, combination of coverage and geographic forwarding in WSNs has been overlooked thoroughly. Here, based on the fact all sensors are believed to be always active when forwarding data. However, this belief is not useful for real world applications. According to the survey, this is the first study of geographic forwarding on duty-cycled CWSNk. This work is an effort complementing previous opportunistic multi-hop routing for wireless networks and particularly the one by Nath and Gibbons.

TABLE I. THE PARAMETERS USED FOR SIMULATION

Number of nodes	50
Number of packets send	537
Number of packets received	527
Packet delivery ratio	98.1378 %
Delay	0.00311906 ms
Throughput	34664.3 bits/sec
Number of packets dropped	10
Total energy consumption	0.654037 Joules
Average energy consumption	0.0133477 Joule/node
Overall residual energy	4899.35 Joules
Average residual energy	99.9867 Joule/node

Initially we have taken 100 Joules of energy for every sensors. In active state of sensors, during transmission 0.03 Joules of energy is consumed and during reception 0.06 Joules of energy is consumed. We have taken 50 nodes for sensing. The number of packets sent is 537 and number of packets received is 527 with 10 packets dropped. The PDR is the ratio of number of packets received to the number of packets send calculated in percentage. Delay is the total of travelling time period of the packets. Throughput is the ratio of how much packets received at the destination in bytes to the difference in final and starting time of receiving and sending of packets respectively. Total energy consumption is calculated by dividing average energy consumption and total number of nodes present in the network.

V. PROPOSED MODEL

The existing Geographic forwarding protocol for WSNs is an energy efficient and practical scheme where sensors are required to maintain local knowledge on geographical locations of one-hop neighbors, to select their next forwarders to progress data towards their destination, rather than maintaining global and detailed information. It also offers joint protocol development, where k-coverage (at least $k \geq 3$ active sensors covered at each point in the field), duty cycling and geographic forwarding are discussed in unified framework. For this, we present our first potential field based solution called Geographic forwarding through fish bladders(GEFIB)[1], where data are forwarded through fish bladders or lenses. Then forwarding with and without aggregation via GEFIB-1 and GEFIB-2 and 3 respectively is performed.GEFIB-1 uses the best relay of sensor. GEFIB-2 uses Locally Aggregated Data (LAD) and GEFIB-3 uses Globally Aggregated Data (GAD).The energy is fairly conserved in the existing model.

Our proposed method includes the degree of coverage with less number of active sensors i.e.) $k \geq 2$ active sensors are considered, where every sensor field is covered by at least two active sensors. There would be less complexity in data forwarding or routing towards the sink and this enhances less usage of nodes for coverage. The nodes are randomly distributed in the environment therefore selecting only two active sensors for routing towards the sink. It follows quick reception of sensed data not forming the tree but which ever node senses act as a forwarder to any other nodes deployed towards the sink. This method is effort complementing existing method with selecting less number of active sensors forming the easiest and quick path creation. By this method we can achieve energy consumption in a better comparison with increase in PDR, decrease in delay, increase in throughput, and handling with less number of sensors. The parameters are same with little modification in the sensor used.

VI. CONCLUSION

We have addressed various protocols for coverage, connectivity, routing, scheduling, geographic forwarding are discussed which contribute in effective way of handling nodes to transfer information to the base station considering energy as the key factor. Several other algorithms determine the placement of nodes for their effective sensing based on the specific application. Then the existing geographic forwarding protocols are described that considers energy as a better comparison. Our joint protocols outperform several previous protocols. It is also useful for applications that require data aggregation and those where all data originated from sources should reach the sink without prior aggregation. Our joint k coverage and geographic forwarding (GEFIB) protocols [1] can be used for applications that demand large degree of coverage, such as interrupting detection and tracking.

Our future work includes the extension of level of usage of sensors to minimize consumption of energy. Then we have planned to implement geographic forwarding on a sensor testbed for its apt performance. Next we plan to design WSNs with models that depict the sensing and communication ranges. Then we have decided to implement GEFIB to 3D (underwater WSNs).

ACKNOWLEDGMENT

The author gratefully acknowledges the insightful comments of anonymous reviewers which helped to improve the quality and presentation of the paper significantly. This work is well supported by Assistant Professor C. Nandagopal, Department of ECE, Karur. This paper will help researchers to enhance more energy conservation methods to increase the network lifetime of sensors.

REFERENCES

Habib.M.Ammari,"CSI: An Energy Aware Cover Sense Inform Framework for k-Covered Wireless Sensor Networks", *IEEE Transaction on parallel and distributed systems*, Vol.23, No. 4, Apr 2012.

G.De-yun, Z. Lin-juan, and W. Hwang-cheng, "Energy saving with node sleep and power control mechanisms for wireless sensor networks", *computer network journal*, 18(1): pg 49–59, Feb 2011.

Jennifer Yick, Biswanath Mukherjee, and Dipak Ghosal, "*Wireless Sensor Networks survey*", Computer Networks journal 52, pg 2292–2330,Apr 2008.

Kemal Akkaya and Mohamed Younis, "*A survey on routing of protocols for wireless sensor networks*", Ad Hoc Networks, 3, pg 325–349, Nov 2003.

S. Nath and P.B. Gibbons, "*Communicating Via Fireflies: Geographic Routing on Duty-Cycled Sensors*," Proc. *Sixth Int'l Conf. Information Processing in Sensor Networks (IPSN)*, pp.440-449, 2007.

G. Xing, X. Wang, Y. Zhang, C. Lu, R. Pless, and C. Gill, "*Integrated Coverage and Connectivity Configuration for Energy Conservation in Sensor Networks*," ACM Trans. Sensor Networks, vol. 1, no. 1, pp. 36-72, 2005.

S. Biswas and R. Morris, "*ExOR: Opportunistic Multi-Hop Routing for Wireless Networks*," Proc. ACM SIGCOMM, pp. 133-143, 2005.

G. Xing, C. Lu, R. Pless, and Q. Huang, "*On Greedy Geographic Routing Algorithms in Sensing-Covered Networks*," Proc. ACM MobiHoc, pp. 31-42, 2004.

H.M. Ammari and S.K. Das, "Centralized and clustered k-coverage protocols for Wireless sensor networks," *IEEE TC,http://www.computer.org/portal/web/csd1/transactions/tcl#2*, to appear, 2011.

P.Bose, P.Morin, "*Online routing in triangulations*, "SIAMJ.Computing, vol.33, no.4, pp. 937-951, 2004.

C.Huang, Y.Tseng, and H.Wu, "*Distributed Protocols for Ensuring Both Coverage and Connectivity of a Wireless Sensor Network*," ACM Trans. Aerospace and Electronic systems,vol.29,no.2,pp.317-327,Apr.1993

D.Tian and N.Georganas, "*Connectivity maintenance and Coverage Preservation in Wireless Sensor Networks*," Ad Hoc Networks, vol. 3, pp. 744-761, 2005.

H.Zhang and J.Hou, "*Maintaining Sensing Coverage and Connectivity in Large Sensor Networks*," Ad Hoc and Sensor Wireless Networks, vol. 1,nos.1/2,pp.89-124,2005.

M. Zorzi and R. Rao, "Geographic Random Forwarding (GeRaF) for Ad Hoc and Sensor Networks: Multihop Performance," *IEEE Trans. Mobile Computing*, vol. 2, no. 4, pp. 337-348, Oct.-Dec.2003.

[15] Z.Liu, O.Zheng, L.Xue, X.Guan,"A distributed energy efficient clustering algorithm with improved coverage in wireless sensor networks", *Elsevier journal*, Future generation computer systems, vol.28, pp.780-790, 2012.

[16] D.Dimokas, D.Katsaros, Y.Manolopolos,"*Energy-efficient distributed clustering in wireless sensor networks*", J.Parallel Distrib.Comput., vol.70, pp.371-383, 2010.

[17] W.Heinzelman, A.Chandrakasan, and H.Balakrishnan,"An Application-Specific Protocol Architecture for Wireless Micro sensor Networks," *IEEE Trans.Wireless Comm*., vol.1, no.4, pp.660-670, Oct.2002.

[18] Y.Bi, Na.Li, Limin sun," DAR: An energy balanced data gathering scheme for wireless sensor networks", Computer communication, vol.30, pp. 2812-2825, 2007.

[19] J.N.Al-Karaki, R.Ul-Mustafa, A.E.Kamal,"*Data aggregation and Routing in wireless sensor networks*", Computer networks, vol.53, pp. 945-960, 2009.

[20] G.W.Denardin, C.H.Bariquello, A.Campos, R.Nederson do Pardo,"*A geographic routing hybrid approach for void resolution in Wireless sensor networks*", The Journal of system and software, vol.84, pp.1577-1590, 2011.

[21] P.Tipler.*Physics for Scientists and Engineers: Electricity, Magnetism, Light, and Elementary Modern Physics*, fifth ed.W.H.Freeman, 2004.