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Energy balanced routing method for wireless sensor networks

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Abstract: Routing is a process of selecting shortest path for packets transfer from source node to destination node in a wireless sensor networks. Different types of routing methods are available out of which the best algorithm will consume less energy wastage in the routing process. Here we discussed in this paper Energy Balanced Routing Method based on Forward Aware Factor (FAF-EBRM) compared with LEACH and three parameters NLN, FAF and PRR which are evaluated. In our proposed method the next hop node is selected according to the awareness of link weight and forward energy density. The important advantage of using this method is to balances the energy consumption of nodes and increases the function life time (FL). Various matrices of NS 2 simulation carried out to study the performance under setup conditions. The proposed method evaluation studies shows that FAF-EBRM outperform to that of LEACH protocol.

Keywords: Cluster, Energy Balanced Routing Method (EBRM), FAF-EBRM, Routing, Wireless sensor networks (WSNs).

1 Introduction

Wireless sensor networks has been an active research area over the past few years because it is an important part of industrial application. It is a self-organization wireless network

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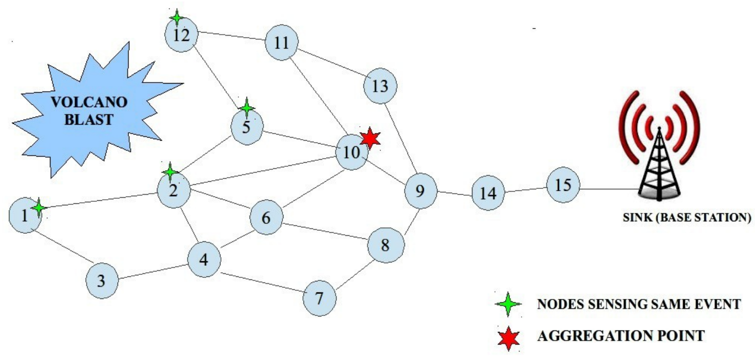

Figure 1: Data aggregation-aware routing

system constituted by numbers of micro sensors with limited energy. They are deployed to monitor the sensing field and collect information from physical or environmental condition. These sensors co-operatively pass the collected data through the network to a main location. Due to the limited energy and communication limitation of sensor nodes, it seems especially important to design an energy efficient routing protocol for WSNs. Energy consumption is an important factor in the architecture designs of WSNs.

Traditionally, there are two approaches to accomplish the data collection task: Direct communication and Multi-hop forwarding. In one hop wireless communication, the sensor nodes upload data directly to the sink, from long communication distances that degrade the efficiency. On the other hand, in multi-hop forwarding, data are transferred from the nodes to the sink through multiple relays, and thus communication distance is reduced [1].However, when node occupies for longer period for data transfer its energy will deplete thereby degrades the network performance. Clustering is an effective technique to reduce energy consumption in WSNs[2]. In clustering algorithm, a node in a network will be selected as the cluster heads (CHs) and all other nodes will act as a cluster members(CMs). CMs will form connections with the CHs collect data from the given cluster. In WSN clustered hierarchical routing protocols, sometimes CMs is closer to the sink than CH, it transmit data to sink via CH. This backward transmission result in wastage of energy. A possible strategy to optimize the routing task is to use the available processing capacity provided by the intermediate sensor nodes along with the routing paths known as data-centric routing or in-network data aggregation. Data aggregation is an effective technique to save energy in WSNs. For more efficient and effective data gathering with a minimum use of the limited resources, sensor nodes are configured smartly ([3], [4], [5]). Figure 1 shows the model of data aggregated aware routing.

Due to the inherent redundancy in raw data gathered by the sensor nodes, the network aggregation is used to decrease the communication cost by eliminating redundancy and aggregate information. One advantage of data redundancy is to increase data accuracy, and other is to reduce communication load to save energy. One of the main challenge in routing algorithms for WSNs is to guarantee the delivery of the sensed data even in the presence of nodes failures and interruptions in communications. This failures become even more critical when data aggregation is performed along with the routing paths with aggregated data contain information from various sources. Whenever one of these packet is lost, a considerable amount of information will also be lost.

2 Related work

2.1 Low Energy Adaptive Clustering Hierarchy(LEACH)

LEACH is the first network protocol uses hierarchical routing for wireless sensor networks to increase the life time of the network. All the nodes in a network organize themselves into local clusters, with one node acting as the cluster-head. All non-cluster-head nodes transmit their data to the cluster-head, while the cluster-head node receive data from all the cluster members, perform signal processing functions on the data (e.g., data aggregation), and transmit data to the remote base station. Therefore, being a cluster-head node is much more energyintensive than being a non-cluster-head node. Thus, when a cluster-head node dies all nodes that belongs to the cluster lose communication ability [6],[7]. LEACH incorporates randomized rotation of the high-energy cluster-head position such that it rotates among the sensors in order to avoid draining the battery of any one sensor in the network[8]. In this way, the energy load associated with being a cluster-head is evenly distributed among the nodes using TDMA schedule. In addition, each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase where several frames of data are transferred from the nodes to the cluster-head and onto the base station [9].

2.2 Set-up phase

In LEACH, nodes take autonomous decisions to form clusters by using a distributed algorithm with out any centralized control. Figure 2 shows the LEACH protocol illustration.

No long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. In addition, no global communication is needed to set up the clusters. The cluster formation algorithm is designed in such a way that nodes act as cluster-heads for approximately the same number of time. Here it is assumed that all nodes start with the same amount of energy. Finally, the cluster-head nodes should be spread throughout the network, as this will minimize the distance the non-cluster-head nodes need to send their data. A sensor node chooses a random number r between 0 and 1. A threshold value $T(n)$ is given in Eq.(1) as follows

$$T(n) = \frac{p}{1-p} \times (r \pmod{p-1}) \tag{1}$$

where

$$p = \text{the cluster head probability}$$

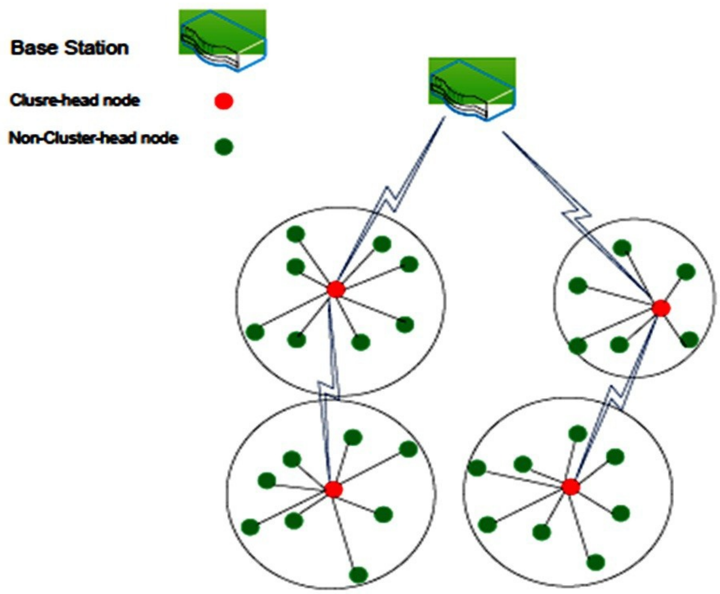

Figure 2: Illustration of LEACH Protocol

$$r = \text{a random number}$$
$$T(n) = \text{a threshold value}$$

If this random number is less than a threshold value $T(n)$ the node becomes a clusterhead for the current round.

The threshold value is calculated based on the above given equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, p is cluster head probability. After the nodes have elected themselves to be cluster-heads, it broadcasts an advertisement message (ADV). This message is a small message containing the node's ID and a header that distinguishes this message as an announcement message. Each non-cluster-head node determines to which cluster it belongs by choosing the cluster-head that requires the minimum communication energy, based on the received signal strength of the advertisement from each cluster-head.

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits a join-request message (Join- REQ) back to the chosen cluster-head. The cluster-heads in LEACH act as local control centers to co-ordinate the data transmissions in their cluster. The cluster-head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This ensures that there are no collisions among data messages and also allows the radio components of each non cluster-head node to be turned off at all times except during their transmit time,

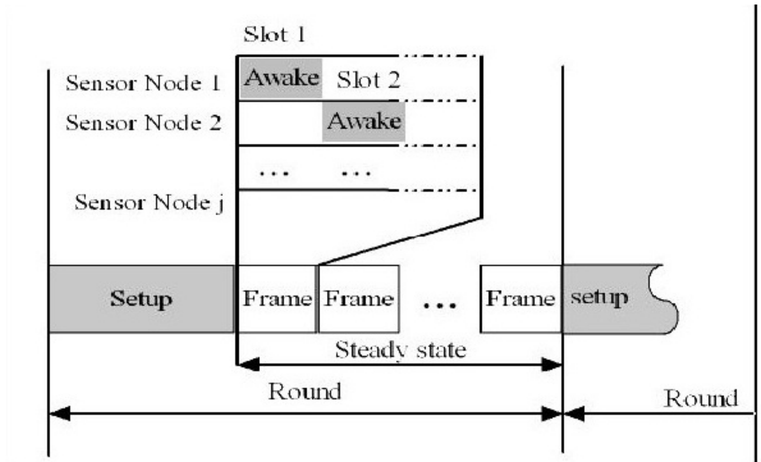

Figure 3: One round of LEACH operation

thus minimizing the energy dissipated by the individual.

2.3 Steady-state phase

The steady-state operation is broken into frames, where nodes send their data to the cluster-head at most once per frame during their allocated transmission slot. The set-up phase does not guarantee that nodes are evenly distributed among the cluster head nodes.

Therefore, the number of nodes per cluster is highly variable in LEACH, and the amount of data each node can send to the cluster-head varies depending on the number of nodes in the cluster. To reduce energy dissipation, each non-cluster-head node uses power control to set the amount of transmits power based on the received strength of the cluster-head advertisement.

The radio of each non-cluster-head node is turned off until its allocated transmission time. Since all the nodes have data to send to the cluster-head and the total bandwidth is fixed, using a TDMA schedule is efficient use of bandwidth and represents a low latency approach, in addition to being energy-efficient. Figure 3 shows one round of LEACH operation.

The cluster-head must keep its receiver on to receive all the data from the nodes in the cluster. Once the cluster-head receives all the data, it can operate on the data and then the resultant data are sent from the cluster-head to the base station

When the network diameter is increased beyond certain level, distance between clusterhead and base station is increased enormously. This scenario is not suitable for LEACH routing protocol in which base station is at single-hop to cluster-head. In this case energy dissipation of cluster-head is not affordable. To address this problem Multi-hop LEACH is proposed in.

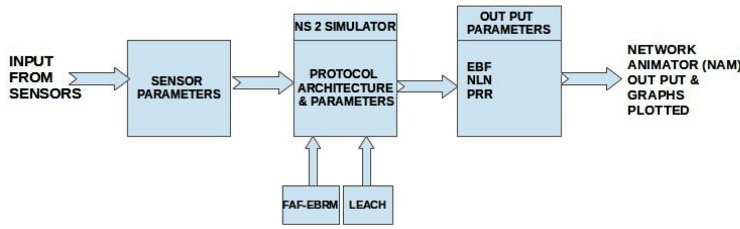

Figure 4: Block diagram of proposed method

2.4 Forward aware factor-energy balanced routingmMethod (FAF-EBRM)

In WSN clustered hierarchical routing protocol, sometimes cluster members in a cluster may be nearer to the sink than the CH, should transmit data to CH first. It results backward transmission of data and leads to waste of energy.

In this method, an energy-balanced routing protocol is designed that uses forward transmission area(FTA) based on position of sink and final data flow direction. In other words, FTA define forward energy density which constitutes forward-aware factor with link weight.

Here we propose a new communication protocol based on forward-aware factor, to balance the energy consumption and prolonging the network function lifetime [10].

In FAF-EBRM, every time node i finishes transmission, and then the point strength of the next-hop node j is checked. If it is less than average value of all of the sensors strengths in FTA, the local topology reconfiguration mechanism should be launched in node i's FTA.

3 Proposed method

The proposed protocol is Enhanced Forward Aware Factor-Energy Bal-anced Rout-ing Method (EFAF-EBRM) based on data aggregation technique that has some key aspects such as a reduced number of messages for setting up a routing tree architecture, maximized number of overlapping routes, high aggregation rate, reliable data aggregation and transmission. According to data transmission mechanism of WSN, we quantify the forward transmission area, forward energy density that constitutes forward-aware factor with link weight. The block diagram of this proposed project is shown in Figure 4.

Input is the sensor data collected from the sensors distributed in a large geographical area. These data inputs from several sensor parameters are analyzed based on the routing algorithm programing is done in NS-2. Figure 4 shows the two protocols compared in this project has two small blocks. These two protocol parameters are analyzed and its observation is plotted as graph. Using a Graphical user interface provided by network animator, the cluster formation message passing , packet drops and packet transmission between nodes also been observed.

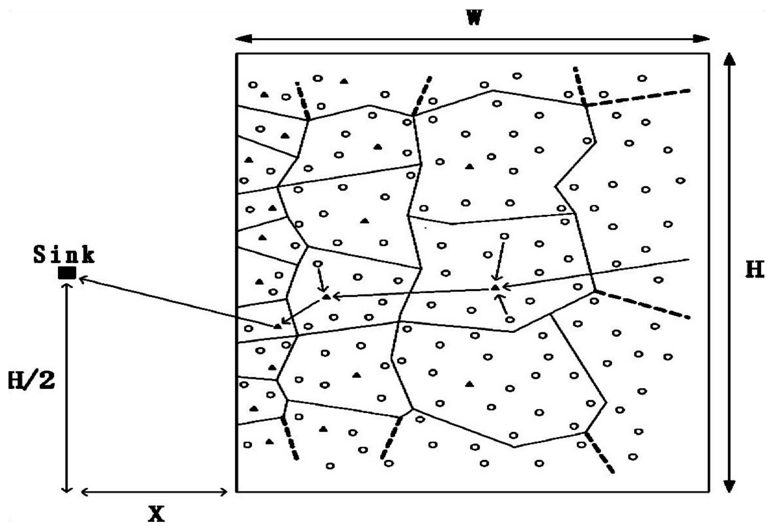

Figure 5: Map of sink and sensor node distribution

4 Model setup

Regional central node (cluster head) receives data from all the CMs and then transfers to the sink node.Following are the setup conditions of the network model.

1. All sensor nodes are isomorphic and have limited energy and communication ability. A node is represented as i.
2. CH is more energy intensive than a CM. Thus, when a CH in a cluster dies, all the CMs inside that cluster lose communication ability.
3. According to distance to receiver, nodes are selected based on its highest transmission power.

The sink node can broadcast advertisement message to all nodes in the sensing field. The distance between source and receiver can be determined by received signal strength. When the data transmission distance is more than certain threshold d_0, the energy consumption would rise sharply. The threshold value is given by

$$d_0 = \sqrt{\frac{\epsilon_{fs}^2}{\epsilon_{mp}}} \tag{2}$$

where ϵ_{fs} and ϵ_{mp} are the energy coefficients.

4.1 Establishment of the network

Let FTA(i) be the forward transmission area of node(i), $N(i)$ be the set of nodes that have communication link with node (i), $N'(i)$ be the set of nodes of $N(i)$ that have edge with

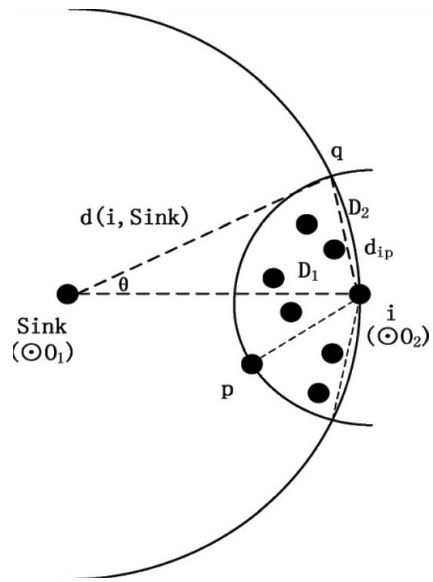

Figure 6: Forward transmission area of node i

node i, d_{ij} be the distance between node i and node j. Consider a circle $\odot O_1$ with sink as the centre and another circle $\odot O_2$ with node, i as the centre and d_{ip} as the radius as shown in Figure 6.

$$W_{ij} = \frac{\rho(E_i(t)E_j(t))^{\psi}}{(d(i,j)^2)^{\eta}(T_{ij}(t))^z} \tag{3}$$

$$d_{ip} = \max(d_i j) \tag{4}$$

This paper proposes an energy balanced routing protocol that uses forward transmission area (FTA) based on position of sink and final data flow direction. In Figure 6, the arc of circle $\odot O_1$ shows the possibility of backward transmission of node i. Circle $\odot O_2$ contains all nodes that directly connected with node i. These 2 circles contains all possible next nodes under topology and routing algorithm. FTA(i) is the overlap section of these 2 circles.

Using Eq.(4), the area of FTA (i) is $S_{\text{FTA}}(i)$, and it can be written as

$$\left(\frac{2}{3}\pi - \frac{\sqrt{3}}{2}\right)[\max(d_{ij})]^2 \leq S_{\text{FTA}}(i) < \frac{1}{2}\pi[\max(d_{ij})]^2 \tag{5}$$

We write

$$d_1 = d(i, \text{ sink }), \quad d_{ip} = \max(d_{ij}) = d_2.$$

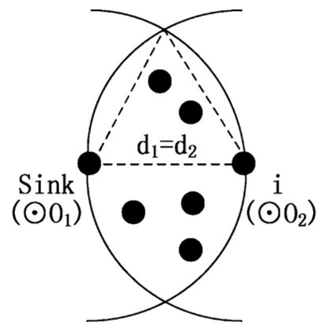

Figure 7: Minimum FTA of node i

According to cosine theorem, angle θ can be written as

$$\theta = \arccos\left[1 - \frac{1}{2}\left(\frac{d_2}{d_1}\right)^2\right] \tag{6}$$

Consider a case in which sink is a neighbour of node i as shown in Figure 7. In this case, d_1 become equal to d_2. If $d_1 = d_2$, then the minimum area of FTA(i) becomes

$$\left(\frac{2\pi}{3} - \frac{\sqrt{3}}{2}d_2^2\right).$$

Consider an another case in which d_1 tends to infinity as shown in Figure 8. In this case, the maximum area of FTA(i) is $\pi\frac{d_2^2}{2}$. When the radius of $\odot_1$ become infinity, its arc tends to be a straight line. This arc passes the centre of $\odot_2$ and approximately dividing $\odot_2$ equally. The area of FTA(i) satisfies the inequality:

$$0 < S_{\text{FTA}} < \frac{1}{2}\pi d_0^2 \tag{7}$$

where d_0 is the communication radius. The nodes forward energy density FED(i,t) satisfies the following equality.

$$\text{FED}(i,t) = \frac{\sum\limits_{j\in\text{FTA}(i)} E_j(t)}{S_{\text{FTA}}(i)}, \tag{8}$$

where $E_j(t)$ is the energy of node j at time t and the numerator in Eq.(8) represents energy of all the neighbours combined in function FTA(i). The forward aware factor (FAF) of the transmission link between node i and node j can be written as

$$\text{FAF}(i,j) = \alpha\frac{\text{FED}(j)}{\sum\limits_{j\in A(i)}\text{FED}(j)} + \beta\frac{w_{ij}}{\sum\limits_{j\in A(i)} w_{ij}} \tag{9}$$

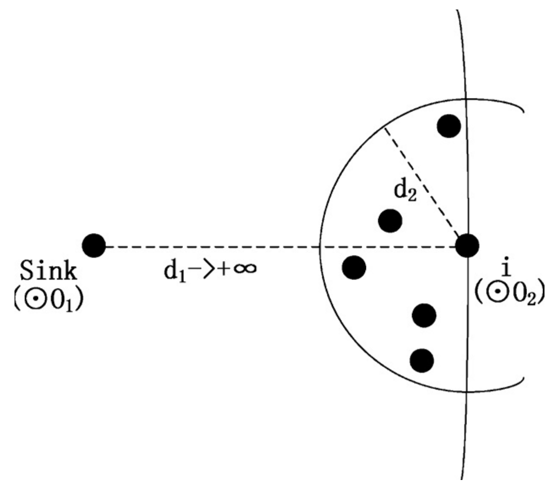

Figure 8: Maximum FTA of node i

In the above equation, the first term represents the FED of all possible next hop nodes that means the ability to transmit data. The second term represents the weight of transmission link which is used to select next hop node directly. In Eq.(9), the denominator of the first term represents FAF of all the neighbours combined in FTA(i) and that of second term represents all of the link weights combined that i has in FTA. α and β are positive harmonic coefficients and they are related by

$$\alpha = \beta = 1. \tag{10}$$

5 Algorithm

The routing algorithm of FAF-EBRM is given below.

Step 1. Determine FTA(i) and all of the possible next-hop nodes of node i. First, taking the communication radius, determine the set of all nodes that have edges with i, $N'(i)$. Select the nodes that are closer to Sink than i, which constitute the set of all of the possible next-hop nodes and the furthest node determine FTA(i).

Step 2. Determine FTA(j) and S FTA(j) of each possible next-hop node. Determine FTA(j) as we determined FTA(i).

Step 3. Calculate FED(j) of each possible next-hop node according to Eq.(8).

Step 4. Calculate the weight of edges between i and each nodes.

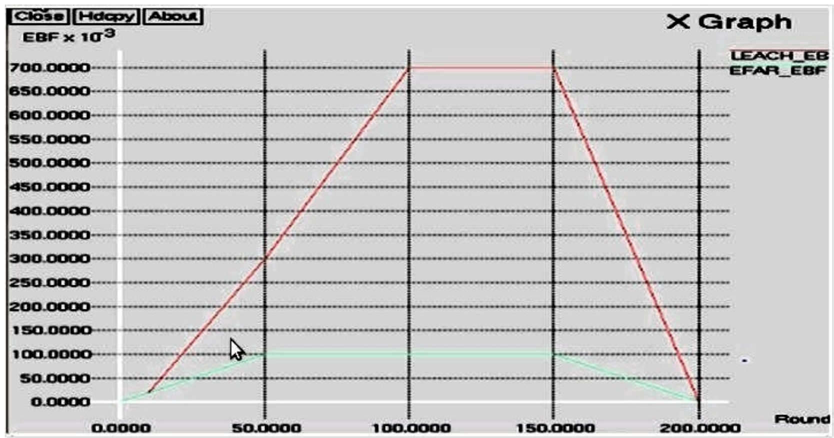

Figure 9: Simulation showing comparison of Energy Balanced Factor (EBF)

Step 5. Calculate FAF of each possible transmit link by using Eq.(9). Choose the next-hop node using the equation below:

$$j = \max[\text{FAF}(ij)] \tag{11}$$

Step 6. If there is no node closer to Sink than i in $N'(i)$, directly compare FAF of all of the nodes in $N'(i)$, and choose the next-hop node according to Eq.(10). If there is no node in $N'(i)$, i will increase the transmit power to get a longer radius than d_0 until connected with another node, or i will abandon the packet.

Step 7. If Sink is among the forward transmit nodes, i will transmit data directly to Sink and accomplish the procedure.

6 Results and analysis

Here, we compare LEACH and FAF-EBRM by three parameters: energy-balanced factor (EBF), number of last-surviving nodes (NLN) and function lifetime (FL), packets reception radio (PRR). To measure the balance of energy consumption of routing protocols, EBF is defined as the standard deviation of all the node's residual energy.

$$\text{EBF} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[E_i(t) - E_{\text{avg}}]^2}, \tag{12}$$

where N is the number of the whole network nodes, $E_i(t)$ is the residual energy of node at time and $E_{\text{avg}}(t)$ is the average value of the residual energy of all of the nodes.

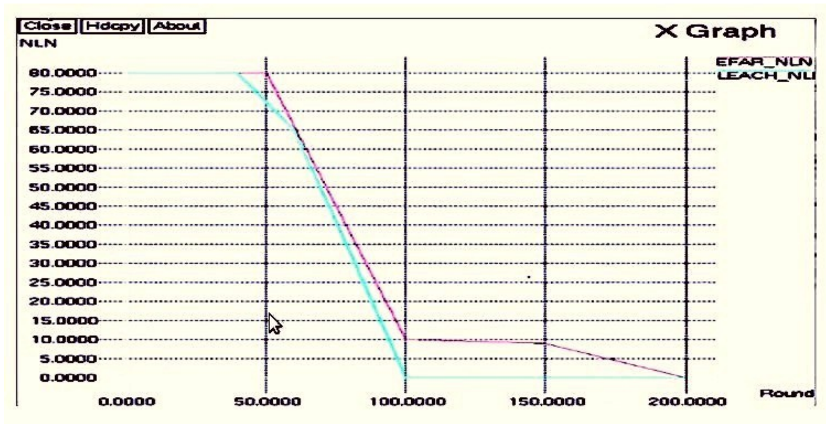

Figure 10: Simulation showing comparison of Number of Last-surviving Nodes (NLN)

Figure 9 shows comparison graph of EBF with energy balance factor on Y axis and number of rounds on X axis. From the simulation we observed that, if the number of rounds increases from 0 to 50, energy has increased by 50%. Again when rounds are increased from 50 to 100 energy has increased by 75% .It remains at 75% up to round 150. From rounds 150 to 200 it will decreases to 0.

Function lifetime (FL) is directly related to NLN; the definition and requirement of FL is different under different conditions, as some require no death node, and some can still work when a certain percentage of nodes still work. In our experiment, we consider two conditions of FL, one is the time from the network begins to the first death of the nodes, another is the time from the network begin to half the nodes dead.

Figure 10 shows comparison graph between number of last surviving nodes and number of rounds, with NLN on Y axis and number of rounds on X axis. From the simulation we observed that, if the number of rounds increases from 0 to 40 both LEACH and FAF retains its NLN as 80 that means all nodes are active. But from round 40 to 50 LEACH loses its 10 nodes but FAF remains as it is.

When rounds increase from 50 to 60 FAF also loose 10 nodes. As round continues from round 60 to 100 approximately equal number of nodes dies off for both protocols. From rounds 100 to 150, all nodes of LEACH dies off, but 10 nodes of FAF will survive up to round 180. This shows that energy balancing is more better in FAF than LEACH.

PRR means the ratio of the data that sink actually received to the data that sink is supposed to be received. PRR can measure WSN work situation intuitively. Figure 11 shows comparison graph of PRR with packet reception ratio on Y axis and number of rounds on X axis.

From the simulation we observed that, if the number of rounds increases from 0 to 40 both LEACH and FAF retains its PRR as 80%. But from round 40 to 50, then LEACH decrease by 70% but FAF remains as 80%. Further as rounds increases from 50 to 60, then

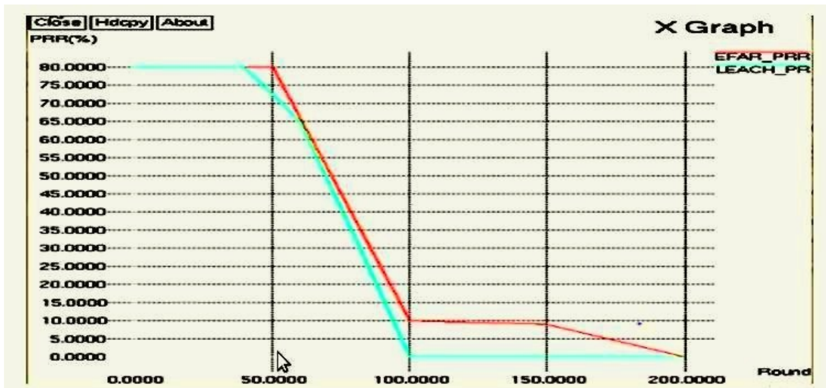

Figure 11: Simulation showing comparison of Packet Reception Ratio(PRR in %)

FAF and LEACH decrease up to 65% of its PRR value. PRR remains constant for 60 to 100 rounds approximately. Beyond 100 round PRR of LEACH falls to zero. FAF still maintains up to round 180.

7 Scope and future work

Energy balanced routing algorithms play an important role in event-based WSNs. In this work, we compared the FAF-EBRM and LEACH algorithm. By maximizing the aggregation points and offering a fault tolerant mechanism to improve delivery rate, the expected results are EFAFEBRM will outperform the FAF-EBRM and LEACH algorithms under evaluation scenarios regarding scalability, communication costs, delivery efficiency, aggregation rate, and aggregated data delivery rate. Also, we expected our proposed algorithm has some key aspects required by WSNs aggregation aware routing algorithms to reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, and reliable data aggregation and transmission.

The goal is to find a balance between the overhead and the quality of the routing tree. In addition, new strategies will be devised to control the waiting time for aggregator nodes based on two criteria: average distance of the event coordinators, and spatial and semantics event correlation.

In future we propose EFAF-EBRM algorithm was extensively compared to two other known routing algorithms, the FAF-EBRM and LEACH. As future work, spatial and temporal correlation of the aggregated data will also be taken into consideration as well as the construction of a routing tree that meets application needs. We also plan to modify the Proposed algorithm to stochastically select nodes that will be part of the communication structure.

References

[1] Chakraborty A, Chakraborty K, Mitra S K and M K Naskar (2009), "An Optimized Lifetime Enhancement Scheme for Data Gathering in Wireless Sensor Networks", IOSR Journal of Electronics and Communication Engineering (IOSRJECE), Vol. 56 No. 8 pp.554-560.

[2] Eu T, Seah K G and Tan H P (2009), "Routing and Relay Node Placement in Wireless Sensor Networks Powered by Ambient Energy Harvesting", Proceedings of Wireless Communications and Networking Conference, Vol. 45 No. 32 pp.1345-1352.

[3] Defago X, Nguyen L T, and Shinoda Y (2008), "An Energy Efficient Routing Scheme for Mobile Wireless Sensor Networks", Proceedings of Wireless Communications and Networking Conference, Vol. 88 No. 6 pp.234-241.

[4] Doerner K, Gutjahr W J and Hartl R F (2001), "Ant Colony Optimization in Multiobjective Portfolio Selection", Proceedings of the 4th Metaheuristics International Conference, Vol. 34 No. 11 pp.345-354.

[5] Erdogan A T and Zhao J (2006), "A Novel Self-organizing Hybrid Network Protocol for Wireless Sensor Networks", Proceedings of the First NASA/ESA Conference on Adaptive Hardware and Systems, Vol. 67 No. 9 pp.542-549.

[6] Boavida F, Camilo C, Carreto J and Silva S (2006), "An Energy-Efficient Ant-Based Routing Algorithm for Wireless Sensor Networks", Book titled "Ant Colony Optimization and Swarm Intelligence," Springer, Berlin, Vol. 35 No. 9 pp.879-885.

[7] Chen Y, Liu X and Zhang D (2012), "Improvement of LEACH in Wireless Sensor Networks Based on Balanced Energy Strategy", International Journal of Engineering Trends and Technology (IJETT), Vol. 44 No. 27 pp.1478-1486.

[8] Balakrishnan H, Chandrakasan A, Heinzelman W R(2000), "Energy Efficient Communication Protocol for Wireless Microsensor Networks", IEEE, Proceedings of the Hawaii International Conference on System Sciences, Vol. 81 No. 1 pp.41-47..

[9] ho Y, Heo J and Hong J (2007), "PEACH: Power-efficient and adaptive clustering hierarchy protocol for wireless sensor networks", Journal of Computer Communications, Vol. 30 No. 7 pp. 28422852.

[10] Attea B A and Khalil E A (2011), "Energy-aware evolutionary routing protocol for dynamic clustering of wireless sensor networks", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) Vol. 122 No. 1 pp.104-124.