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A LOCAL TOPOLOGY RECONFIGURATION MECHANISM TO IMPROVE THE ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORK

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ABSTRACT

A wireless sensor network (WSN) is a self organizing wireless network system consists of number of energy limited sensor nodes. Since sensor nodes are battery powered devices, they have limited processing and transmission power and with limited communication ability. In order to transmit sensing data to receiver effectively, it is necessary to design an energy efficient routing protocol for WSNs. The nodes with greater signal strength will have more communication link and result in faster energy consumption as a whole network cannot always work under the same topology structure. A topology reconnecting mechanism of the cluster head rotation algorithm is needed. This paper presents an Enhanced Forward Aware Factor -Energy Balanced Routing Method (EFAF-EBRM) based on the selection of appropriate cluster head to improve the energy efficiency . In this technique the sensor node may prefer to select cluster head that makes the total energy consumption least.This proposed cluster formation strategy decreases the communication overhead and increses the packet delivery ratio.More over this technique over come the problem in the existing rouitng method FAF-EBRM when local topology reconfiguration is needed. In this method an optimal solution for cluster head selection is proposed .The sensor nodes in the proposed algorithm pick out their appropriate cluster heads rather than the nearest for the sake of energy efficiency The newly proposed cluster formation strategy reduces the delay even for the long distance link. Simulations results also prove that the proposed cluster formation strategy is better performance compared with FAF-EBRM and LEACH in terms of Energy balanced factor, Network lifetime, communication over head and delay.

Keywords: *Forward Aware Factor(FAF), Cluster Formation ,Communication Over Head ,Wireless Sensor Networks(Wsns).*

1. INTRODUCTION

A Wireless Sensor Networks (WSNs) consists of tiny sensing device that are physically small, communicate wireless among each other. Due to the limitation of their physical size, the sensors tend to have short storage space, energy supply and communication bandwidth so limited that every possible means of reducing the usage of these resources is aggressively sought. The use of the WSN potential will provide efficient and costs-effective solutions for several problems[1][2]. Hot spots in a WSNs emerge as locations under heavy traffic load. Nodes in such areas quickly drain energy resources, leading to disconnection in network services. Cluster based routing algorithms in WSNs have recently gained increased interest, and energy efficiency is of particular interest. However it is necessary to implement mechanisms or procedures to deal with the sensor constraints. The hierarchal organization of the sensors ,grouping them and assigning those specific tasks in to the group before transferring the information to higher levels, is one of the mechanism proposed to deal with the sensors limitations and is commonly referred to as clustering. The creation of clusters in a WSN field is generally done by taking into account the proximity between the sensors, measured through the radio frequency signal they emit. Each cluster has a cluster head CH which is the node that directly communicate with the sink (base station) BS for the user data collection. By assuming the roles within a cluster hierarchy, the nodes in a WSN can control the activities they perform and therefore reduce their energy consumption .However the election of when to act

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as a simple data provider (saving energy) and when to act as gateway (cluster head) between the nodes and then base station is difficult problem[1][4]. To make this decision it is necessary to take into account several aspects including power level signal, transmission schedules, nodes localization and networking function. Clustering helps in solving some of the sensors constraint by reducing the cost (energy consumption) of transmitting data to base station. Clustering technique reduces the power consumption in the devices facilitating the gathering of sensed data, and maximizing the routing process execution and allowing scalability.

Many energy efficient routing algorithms and protocols have been proposed to prolong network life time for WSNs in recent years [19] .In most of the routing scenarios, the sink node is usually assumed to be fixed either inside or outside the WSNs. This will inevitably cause the hot spot phenomenon, primarily then sensors close to sink nodes will have more traffic load to transmit than nodes further away from the sink nodes under multi hop transmission. 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, which may result in long communication distances and degrade the energy efficiency of sensor nodes. 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 [11]. However, since nodes closer to the sink have a much heavier forwarding load, their energy may be depleted rapidly, which degrades the network performance.

In EFAF-EBRM, a spontaneous reconstruction mechanism for local topology is designed based on the maximizing the co-alive life span and minimizing the total energy consumption, in this routing method protocol the nodes pick out their appropriate cluster heads rather than the nearest for the sake of energy efficiency.This paper aims to balance the energy consumption based on the requirement of the network. First case the total energy expenditure of a packet from the departure node to the destination base station is reuced when the sensor node tends to select a cluster head which minimizes the total energy consumption of a single packet delivering and in the second case the node prefers to choose a cluster head that maximizes the life time of both, even if more energy is consumed.

The rest of paper is orgaized as follows : Section 2 presents the related work.Section 3 describes the problem statement Section 4 presents the proposed method performance anlaysis Section 5 gives the simulation results Section 6 represents a summary of conclusion.

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2. RELATED WORK

2.1 Low energy adaptive clustering hierarchy (LEACH) protocol

LEACH protocol is one of the most famous hierarchical routing protocols for wireless sensor networks to increase the life time of network. LEACH, is the probabilistic –based cluster head selection [5].All the nodes in a network organize themselves into local clusters. The protocol is divided into a setup phase each node chooses a random number between 0 and 1 ,if this number is less than certain threshold T(n) the node will broadcast itself as cluster head. The non cluster head node chooses the cluster head with greater signal strength and joins the cluster and then the cluster head node receives data from all of the cluster members and transmits the data to the remote sink. The threshold T(n) is given by

$$T(i) = \begin{cases} p/(1 - p \times r \bmod \left(\frac{1}{p}\right), i \in G \\ 0 \qquad , else \end{cases} \quad (1)$$

Where p is the desired percentage of cluster heads, r is the current round and G is the set of nodes that have not served as cluster heads in the last rounds

LEACH allows randomized rotation of the high-energy cluster-head position such that it rotates among the sensors. In this way, the energy load associated with being a CH is evenly distributed among the sensing nodes. The CH node will know all the sensor node in the cluster. Therefore it can create a TDMA schedule that informs each node exactly when to transmit its collected data.

2.2 Forward Aware Factor –Energy Balanced Routing Method.

In FAF-EBRM a new energy-balance routing protocol that computes forward transmission area(FTA) based on position of sink and cluster node for final data flow direction. In other words, FTA[3] define forward energy density which constitutes forward-aware factor with link weight, and proposed a communication protocol based on forward-aware factor, thus balancing the energy consumption and prolonging the network function

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lifetime. FAF-EBRM network model is shown in the figure 1.

1) All sensor nodes are isomorphic and they have limited energy and communication ability. Here, identifier for a node is represented as 'i'.

2) CH is more energy intensive than a sensor nodes. Thus, when a CH in a cluster dies, all the sensor nodes inside that cluster lose communication ability. However, addition of energy of sink node is possible. But, it is not possible to change the location of nodes and sink after being fixed [3].

3) According to distance to receiver, nodes can vary its 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 thresholdd_0, the energy consumption would rise sharply. The threshold value is given by,

$$d_0 = \sqrt{\varepsilon_{fs}^2 / \varepsilon_{mp}} \quad (2)$$

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

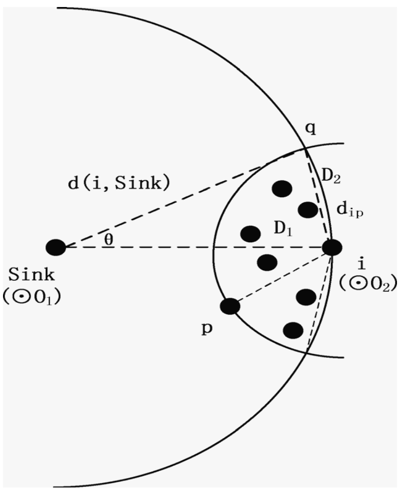

Figure 1: Forward Transmission Area of node i

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 node i, d_{ij} be the distance between node i and node j. Consider a circle

$\odot_1$ with sink as the centre and another circle $\odot_2$ with node, i as the centre and d_{ip} as the radius as shown in figure1:

$$FTA(i) = \odot_1 \cap \odot_2 \quad (3)$$

$$d_{ip} = \max\,(d_{ij}), j \in N'(i) \quad (4)$$

In FAF-EBRM every time node i finishes transmission check the point strength of the next-hop node , if it it less than the average value of all of the sensor's strength in FTA ,the local topology reconfiguration mechanisms should be launched in node i's FTA. Before the topology reconfiguration mechanism is launched the existing link must be removed and new set of FTA(i) should be computed. The node removed may be the possible next hop node when the next transmission is finished. The nodes real –time strength is needed to calculate the sum of strength.

Due to the spontaneous topology reconstruction mechanism 1) communication radius should be computed to find the distance whenever the topology construction changes and as a result communication overhead results 2)The frequent changes adversely affect the performance of the network because the routing method spend more time selecting CH rather than relying on packets. 3) Cluster formation consumes certain amount of energy. Periodic advertisements are needed to form hierarchy this results communication over head in the routing path.4) Change in network traffic will affect the cluster head and sensor node energy level results in re-clustering which is not acceptable as some of the parameters in computing the total energy consumption changes which in turn will affect the throughput and delay.

3. PROBLEM STATEMENT

All exsisting clustering algorithms including the mentioned above FAF-EBRM have concentrated on the data transmission distance and when the distance larger than the threshold d_0 the energy consumption would rise sharply, therefore the communication radius is set to d_0.In the traditional hierarichal cluster based routing protocol LEACH, the primary aim is to balance energy utilization in wireless sensor network .In addition probabilistic-based cluster head selection method is used,each ordinary node chooses its closest cluster head with the largest received signal strength and each meember node slects its cluster head with single hop to reduce the communication distance,in other pont of view the cluster head to based statuion distnace is not considered in the popular routing algorithm. In FAF-EBRM based on uneven clustering the routing algorithm is computed based

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on the forward transmission area FTA and the communication link is determined.The forward energy density FED is calculated to find out the next hop node the whole network cannot always work under the same topolgy structre . As a result the node which which is closer to the sink will result in faster energy consumption. This problem exists in many WSN routing protocols such as ECLP and T-MAC.

In FAF-EBRM ,every time the node after finishes the transmission check the status of the link weight ,it is less than the avearge value of all the sensors strength in FTA the local topology reconfiguration mechanism should be launched. Due to the spontaneous topology reconstruction mechanism communication radius should be computed to find the distance whenever the topology construction changes and as a result communication overhead results .More over in existing protocol FAF –EBRM if the base station is among the forward transmit nodes the cluster member node will transmit the data directly to base station to overcome the backward transmission which result in waste of energy[7] but the node close to sink will exhaust all the energy due to over load in the traffic and biconnectivity results.

4. PROPOSED MEHOD

4.1 Protocol Description for Analysis-EFAF-EBRM

To improve the energy efficiency in wireless communication ,Since wireless communication always consumes higher percentage of enrgy than wired commincation when the data's are trnasmiited to the destination end , to improve the energy efficiency in wireless communication this paper suggests a new cluster formation technique. few modification is done in the exsisting clustering techniqe.

As shown in the figure 2 suppose the N sensor nodes are randomly distributed in rectangular fieldof M x M(m^2).Data are sent to the regional central node (cluster head),then transfered to the sink node (sink) .Each head has commmunication radius R_i to send advertisement .Suppose traditional cluster head slection algorithm has been operated many nodes can receive the messages from more than one cluster head as follows.

$$N_c = \left(\epsilon \sum_{i=1}^{k} \pi R_i^{\,2} - M^2\right)\rho \quad (5)$$

Where N_c represents the number of nodes receiving morethan one advertisment , ρ denotes node density and € indicates the overlapping ratio between the covering area of a cluster heads `and deployment regions of all node. Two cases are considered to minimize the energy consumption. First case all the cluster heads are in square M^2.Second case all heads are at boundaries of the square then €=0.5 therefore the overlapping ratio € is between 0.5 and 1.

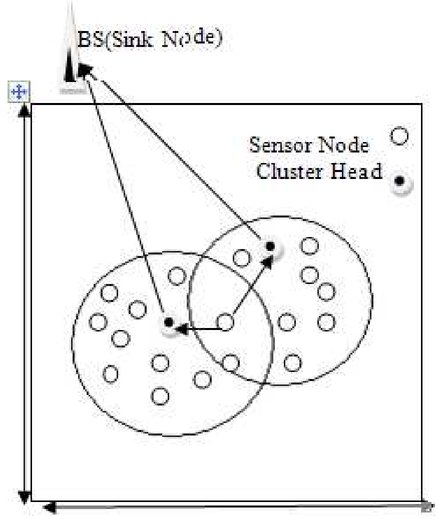

Figure 2: Distribution Map of Sink Node and Sensor Node.

Through LEACH Protocol the Optimal cluster head number is igiven [5]

$$k_{opt} = \sqrt{\frac{2N}{2\pi\, 0.765}} \quad (6)$$

The average node density is $\rho = \frac{N}{M^2}$.Consider allthe cluster heads have the same communication radius R Then

$$N_c = \left(\epsilon\sqrt{\frac{2N}{2\pi\, 0.765}}\,\pi R^2 - M^2\right)\frac{N}{M^2} \quad (7)$$

Suppose for R =0.3M and € =0.5 then

$$N_c = (0.1771\sqrt{N} - 1)N \quad (8)$$

For largely densely deployed network there always exist a considerable number of nodes to have more than one cluster head.

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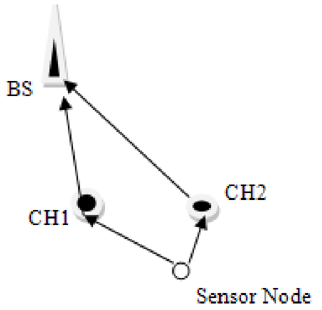

Fig 3: Cluster Member chooses the Head to relay Packets

For the sake of energy efficiency it is necessary to to select the proper cluster head rather than the nearest cluster head consider the figure 3 The member node has to connect to CH2 rather CH1 for the data transmisssion because the energy consumption would rise sharply if the transmission distance is larger however the sensor node save energy in this case but CH2 probably waste energy on transmitting packets to the sinknode.Therfore the total enery consumed for transmitting the data to the base station from the sensor node to the base station is taken in to account.

4.2 Performance Analysis using Radio Model

Under the principle discussed in the section 3 performance analysis is done based on the two sitution cases 1: Nodes tends to select the cluster head which minimizes the total energy consumption of asinglepacket delivering .case 2: nodes prefers to choose a cluster head that maximize the lifetime of both the sensor node and clluster node[10].

4.2.1 Establishment of the model

Assume the energy modelas described in LEACH. The energy to transmit ,receive and aggregate a l-bit message is

$$E_{TX}(d,l) = \begin{cases} l(E_e + \varepsilon_f d^2) & if\ d < \delta \\ l(E_e + \varepsilon_m d^4) & if\ d \geq \delta \end{cases} \quad (9)$$

$$E_{Rx}(l) = lE_e \quad (10)$$

$$E_{agg} = lE_{da} \quad (11)$$

Where d is the distanc ebetween twonodes and E_e is the energy dissipated to prebit. ε_f and ε_m are the factors of free space model and mulitpath model and δ is a threshold to decide which transmisssion model is used and $\delta = \sqrt{\frac{\varepsilon_f}{\varepsilon_m}}$, E_{da} is the energy dissipated on aggregation per bit.

Energy consumption mainly consists of four parts : 1)Transmitting enrgy from node tocluster Head 2) Receiving energy dissipated by a cluster head 3)Aggregation energy spend by a cluster head 4) Transmitting energy from a cluster head to the base station. Thus the total energy dissipation of a l bits packet from sensor node SN to cluster head CH and arrives to base station is expressed as

$$E_t = E_{TX}(d_{s,ch,} l) + E_{Rx}(l) + E_{agg}(l) + E_{TX}(d_{ch,BS}\ \mu l) \quad (12)$$

The aggregation ability of a cluster head is defined as ratio μ therefore the cluster head can aggregate a l bits length packet to be μl bits.

The two factors taht have influenced on the energy consumption can be analyzed on the two cases.

Case 1: Minimizing the total energy consumption.

If the network is able to detect some events as long as there are a few alive nodes,then the sensor node selects the cluster head CH form available CH's can be formulated as:

$$CH = \arg\min E_t$$
$$if\ d_{s,ch} < \delta, \quad \varepsilon_{s,ch} = \varepsilon_f$$
else
$$\varepsilon_{s,ch} = \varepsilon_m$$
$$if\ d_{ch,BS} < \delta, \quad \varepsilon_{ch,BS} = \varepsilon_f$$
else
$$\varepsilon_{ch,BS} = \varepsilon_m$$

Case 2: Maximizing the co-alive lifespan

If the network requires nodes alive as much as possible to collaborate with each other then the network life span is divided into many rounds,node s will choose a CH that makes E_t l ,but this cannot equalize the energy consumption between S and CH this imbalance will greatly degarde the network life time, in oder to overcome this problem node S select a CH that maximize the co-alive life span,to select a CH in inorder to make co-alive life span to be maximum can be formulated

$$CH = \arg\max R_{co}$$
$$R_{co} = \min\{R_s, R_{CH}\}$$
$$= \min\left\{\frac{E_{res}(s)}{E_{r(S,CH)}}, \frac{E_{res}(CH)}{E_{r(CH)}}\right\}$$

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R_s, R_{CH} are the life span ofthe node S and CH respectively. $E_{res}(s), E_{res}(CH)$ are the remaining energy of the S and CH [19].

4.2.2 Design of the EFAF-EBRM.

EFAF-EBRM is used for the large scale WSN for static data collection and event detection.The proposed cluster formation strategy in EFAF-EBRM is independent to the cluster head selection algorithm. The cluster nodes with greater signal strength will have more communication link and result in faster enrgy consumption.A topolgy reconnecting mechanism of the cluster head rotation algorithm is needed[9] .With few alive nodes to detect the event the network choose case1.

Stage 1 : A new round begins and a cluster head slection algorithm runs .The elected cluster head broad cast their advertisment with information about the position to the base station ,their aggregation ability and residual energy.

Stage 2 : Each non-cluster head node collects all received advertisment and calculate the total energy dissipation E_t according to the equation (12).

Stage 3 : Cluster head that makes E_t least and the sensor node belongs to the cluster as long as there are a few alive nodes to improve the energy efficiency.

5. SIMULATION RESULTS

As shown in Table 1 there are 100 sensor nodes deployed in a (200,200) m^2 with the initial energy 0.5 joules .The maximum transmission radius is assumed to be 30 meters R. Simulation were carried out in NS2. In this simulation the objectives of clustering algorithm under test are 1) cluster formation 2) selecting cluster head 3) comparison of various parameters such as energy-balanced factor (EBF), number of last- surviving nodes (NLN) and packets reception radio (PRR) with existing algorithm LEACH and FAF-EBRM is implemented.

TABLE 1: Node specificcation parameters

Simulation tool NS2	
Network coverage	(200,200)m
Number of nodes	**100**
Initial energy	0.5J
R	30m
ε_f	10 pj/bit/m^2
ε_m	0.0013 pj/bitm^4

5.1 EFAF-EBRM Performance Analysis

Figure 4 and figure 5 illustrates the cluster head selection and the cluster formation strategy, a node tends to select cluster head which minimizes the total energy consumption of as single packet delivering

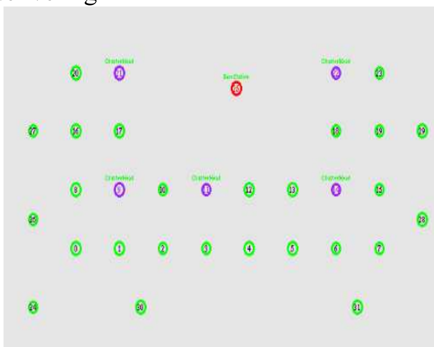

Fig 4: Cluster Head Selctions

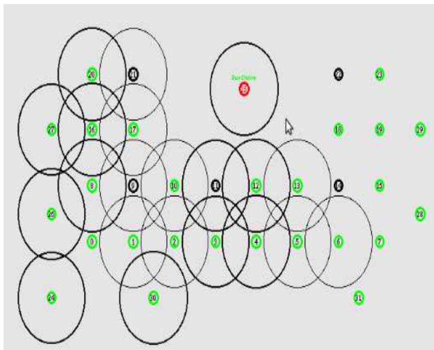

Fig 5: Cluster Formations

To measure the balance of energy consumption of routing protocols, EBF is defined as the standard deviation of all the nodes' residual energy

$$EBF = \sqrt{\left(\frac{1}{N}\sum_{i=1}^{N}[E_i(t) - E_{avg}(t)]^2\right)}$$

(13)

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

In this experiment the number of living nodes (NLN) represent the time from the network begins to the first death of nodes.

PRR is the packet reception ration of the data that sink actually received to the data that sink is supposed to be received. PRR can measure WSN work situation intuitively.

To compare two protocols conveniently and intuitively, EFAF-EBRM also uses round as the

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time scale. Figs. 6–8 show that the EBF, NLN, and PRR of three protocols in 200 rounds experiments. In Fig. 6, the EBF of FAF-EBRM increase slightly at first and keep a stable situation , then increase a little time, and return to 0 as the energy of the whole network is using up. In Fig. 7, the first death of FAF-EBRM node turns up until Round 200, and the procedure of the nodes' death is fast and late. In Fig. 8, the PRR of FAF-EBRM keeps 100% ratio for 200 rounds, and the decline stage accounting for small portion.

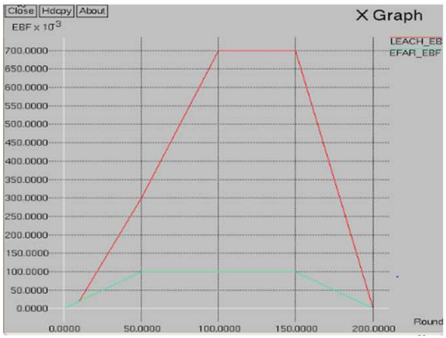

Figure 6: Comparison of Energy Balanced Factor (EBF)

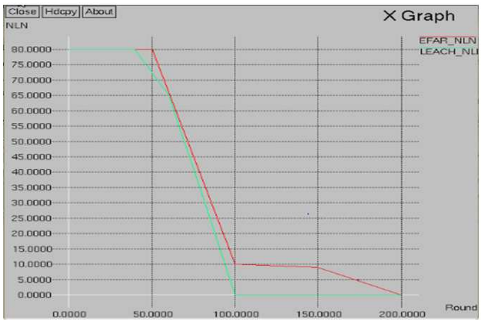

Figure 7: Comparison of Number of Last-surviving Nodes (NLN)

Figure 8: Comparison of Packet Reception Ratio(PRR in %)

The three parameters of EFAF-EBRM is same as that of FAF-EBRM but the proposed new cluster formation technique out performs LEACH. In addition to these parameters, proposed methods have other advantages. The additional advantages of EFAF-EBRM over existing methods 1) Decreases communication overhead 2) Increased throughput and packet delivery ratio.

Communication overhead means the ratio of routing packet to the received packet.

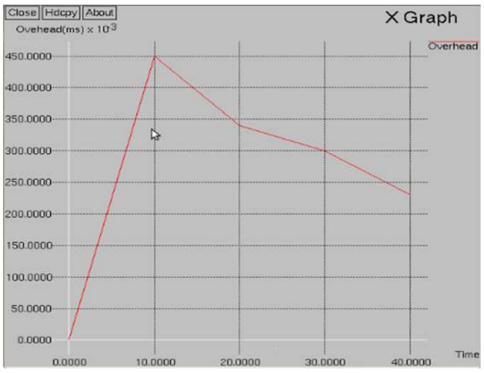

Figure 9: Communication overhead versus time of EFAF-EBRM

Packet Delivery Ratio (PDR) means the ratio of the received packet to the Generated packet.

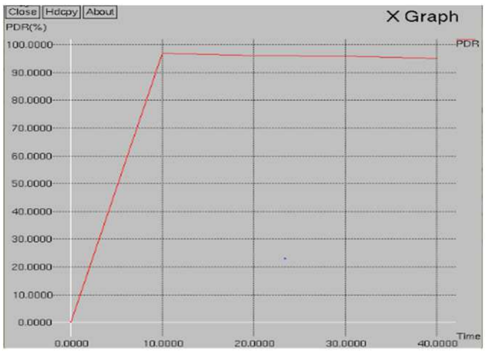

Figure 10: Packet Delivery Ratio versus Time of EFAF-EBRM

Delay means the difference between packet received time and packet transmitted time.

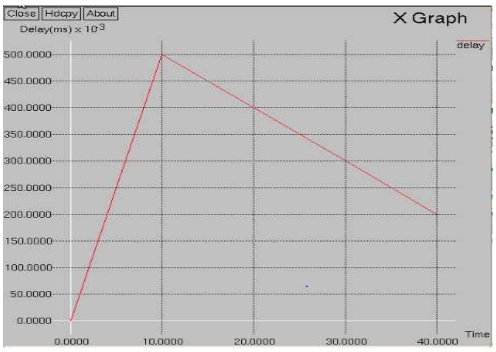

Figure 11:Delay versus Time of EFAF-EBRM

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From the figure 9-11 the simulation results shows the communication overhead and packet delivery ratio gradually decreases as the time increases. The proposed cluster formation strategy EFAF-EBRM has a higher performance than LEACH and FAF-EBRM , which balances the energy consumption, prolongs the function lifetime and guarantees high QoS (such as Energy-Balanced, prolonged network life, Packets Reception Radio) of WSNs.

6. CONCLUSION

This paper proposed an enhanced energy balanced routing method based new clustering formation from the point of cluster members. In this technique the sensor node may prefer to select cluster head that makes the total energy consumption least.This technique is implemented to over come the problem in FAF-EBRM when local topology reconfiguration is needed and to decrease the communication overhead. In the experiments, EFAF-EBRM is compared with traditional LEACH. algorithm and experimental results show that EFAF-EBRM outperforms LEACH, which balances the energy consumption, prolongs the network function lifetime. The performance of the proposed algorithm also increases the throughput by reducing the communication overhead and delay.

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