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ENERGY EFFICIENT CROSS LAYER APPROACH FOR ROUTING OPTIMIZATION IN WSN

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ABSTRACT

In recent time high demand of wireless sensor network (WSN) makes it very popular and the key interest for researchers. WSNs can be implemented in various areas such as in monitoring, health application, agricultural, security application etc. WSNs has key issues during their lifetime due to large number of tiny sensor nodes deployed randomly in hazard places and it is powered by battery. Maximizing the WSNs coverage time is the research motive. For optimization of energy conservation in the network various routing approach presented. Clustering approach enhances the system performance and network lifetime. It is analyzed that the single layer routing approach in WSN network will not greatly affect the network coverage time. Physical layer information used in network layer for the routing and in MAC layer TDMA is considered for slot allocation. Hence a cross layer based approach is presented based on physical, MAC and Network layer. Optimal number of cluster is generated for balancing the energy consumption in network.

Keywords: *cluster, cross layer, MAC, multipath fading*.

I. INTRODUCTION

Wireless Sensor network consists several small sensor devices which is battery constrained. Sensor nodes consume the energy in sensing the surrounding environment, processing of sensed data and in transmission of sensed data. Replacement and recharging of the battery is not possible or infeasible due to its location and random deployment area. Such as it can be deployed in battle field, forest or any hazard places. Hence network coverage time maximization is a challenge. Conventional multi hop data transmission approach is somehow maximize the network time over single hop communication. There are some other challenges in the WSNs due to its nature of deployment such as limited resources, traffic asymmetry, dynamic nature of network, redundant or false transmission of data, balancing of energy, traffic load etc.

In the radio module or in the physical layer lots of energy can be drained at the time of transmission of data packet and receiving of the data packets. In physical layer wastage of energy due to collision of packets, retransmission, nodes ideal listening, and overhead. Energy efficient MAC protocols are designed for avoiding the above problems [3]. In [4] TDMA based energy efficient MAC protocol presented for reducing the delay in the network. This approach considered the slot re-use technique in MAC with TDMA approach. However in [5] they used allocation of slot approach based on MAC layer CSMA/CA techniques for reduced the delay in the network.

Energy optimized multi-hop routing gain attention from the researchers in [1-2] here they target the energy aware routing before transmitting the data packet they considered the energy of link. Multihop communication not fully overcomes the network lifetime problem as intermediate nodes or nodes nearest to the base station die early due to participation in hop communication.

Cluster based approach is also become popular for maximizing the network lifetime. In clustering approach a large sensor network divided into number of cluster. Each cluster has member nodes and their head known as cluster head. Selection of cluster head is done based on the energy level, connectivity and their signal strength. Cluster members transmit their sensed data to the cluster head and cluster head communicate with the base station. LEACH is the base clustering approach in this selection of cluster head done based in rotation [3].Clustered based technique

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is more flexible as nodes can be easily added to the network. Load can also equally distributed in the clustering approach [6].

To overcome the issue of network coverage time, and design an efficient routing approach a cross layer based routing approach is presented in [7]. In this direct communication channel established between the adjacent node protocols. Variables are shared among the layers. Protocol stack in all layers impact the energy consumption [8], hence better interaction among these layers are needed for efficient energy consumption. Cross layer design architecture result in efficient energy consumption. In [9-10] an adaptive cross layer technique is presented for optimization of different layer activity. In this approach clustering and routing at MAC layer both are optimized.

Cluster based cross layer architecture can greatly enhance the network coverage time. It helps in improving the network as well as node capacity and make it more scalable. Transmission of data can be done based on state of channel condition. It also helps in load balancing among the different nodes by using the information of different layers. Cross layer design approach reduce the traffic among the layers.

Based on these studies, a work for maximizing the network coverage time based on homogeneous inter cluster communication approach is presented. Homogeneous cluster have same number of cluster members in each cluster and it must balance the cluster head and their computation overhead. Routing of data packet is based on the cross layer approach and uses the shortest path transmission. Here, a joint optimization of clustering and routing using cross layer approach is presented. A mathematical model is presented for cross layer approach which aid in improving coverage time of network.

The paper organization is as follows: In section two the proposed WSN cross layer approach is presented. Section three experimental results are discussed. The last section consists of conclusion and future work.

II. PROPOSED MODEL

Network Design

Architecture WSN network consist of sensor nodes with one or more base stations. Here, the author considers a single base station or sink node. This approach uses cluster based WSN design. A large network divided into various number of small clusters. Each cluster having equal number of sensor nodes. Each cluster is assigned one cluster head ($\mathcal{CH}$) and rest of the nodes are cluster member ($\mathcal{CM}$) of that cluster. Cluster head are more powerful as it has more RSSI, energy, and connectivity with other nodes. $\mathcal{CM}$ are responsible for the sensing the surrounding data send it to the $\mathcal{CH}$. After receiving the data from member nodes cluster head processes the aggregated data and forward it to the base station.

Let us consider, if suppose the total number of nodes in the network is N.In which H are the total number of cluster head and remaining K nodes are the member nodes. Let each $\mathcal{CM}$ generate ℓ $bits/sec$ and send it to the base station. $\mathcal{CH}$can directly send their data to the sink as $((H+1)th)\mathcal{CH}$ or it can be forwarded through other cluster head as inter-cluster communication as shown in Figure 1.

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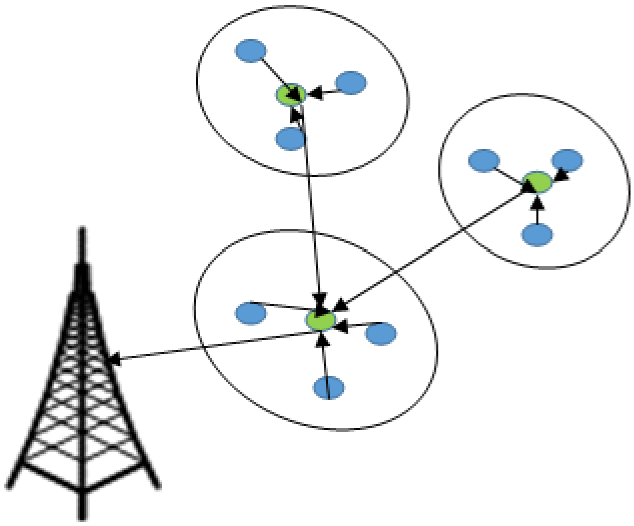

Figure 1 WSN inter cluster communication

Energy depletion rate of $\mathcal{CH}$ is faster than the other member of cluster. As cluster head communicates frequently with the member node and sink node. In Member nodes duty cycle is less and after sending their data they put them self in sleep mode. As TDMA based transmission scheduling is used. While $\mathcal{CH}$ is awake for all the time , listening to their member nodes. Rotation based cluster head selection approach is used for balancing the load of cluster head.

Cross Layer Design Approach

As WSNs coverage time and efficiency can be enhanced through the interaction between different layers. In cross layer approach three different layers are considered namely physical layer, MAC layer and network layer. For physical layer knowledge channel model design is presented in section C and channel information used in Network layer.

A joint technique of MAC and Network layer is presented. For simplicity of the TDMA based slot assignment in MAC layer standards are considered. Each node can transmit their data in their assigned slots only. Assignment of time slot to the nodes reduce the congestion or traffic in the network. Further utilizing the information of physical layer (signal strength) and considering the MAC TDMA a cluster based routing approach is designed in network layer.

Design Channel Model

Channel model design based on the Rayleigh fading approach for communication between the cluster head and between sink and cluster head. Channel gain representation for separation of transmitter and receiver considering separation s,

$$C(s) = P(a_0)\left(\frac{s}{a_0}\right)^{-m}\varphi \qquad (1)$$

Where a_0 represented the closest distance and $P(a_0)$ represent the path loss for closest distance. Path loss exponent represented as m and it can vary between$(2 \leq m \leq 6)$. Fluctuation in Rayleigh fading is represented as φ and it is a normalized random variable. As random received signal strength in wireless communication is also random and hence a received value of signal must be higher than a fixed threshold signal value. $P(a_0)$can be represented as,

$$P(a_0) = \frac{G_r G_t, \lambda^2}{16\pi^2 a_0^2} \qquad (2)$$

Gain of antenna for transmitter and receiver represented as G_t and G_r respectively. Wavelength of carrier frequency is represented asλ

Route Optimization and Clustering Approach

For Let suppose H cluster head as ($p\epsilon 1,2,\ldots\ldots,H$). Assume that the pth cluster head collected inter cluster traffic data as c_p . A vector C is defined for clustering and represented as $C=(C_1,\ldots.C_H)$Each cluster is homogeneous in nature and number of member to each $\mathcal{CH}_p$as c_p/ℓ. Let consider qth cluster head and it belongs to, ($q\epsilon 1,2,\ldots..H+1$). When the inter cluster communication is considered then, $p\neq q$. Inter cluster communication between $\mathcal{CH}_p$ $to\mathcal{CH}_q$ generate data traffic as represented as d_{pq}. Matrix for route optimization,now consider as $\mathcal{R}=H\times(H+1)$ of elements d_{pq}. Where ($p=1,2,\ldots\ldots,H$) and ($q\epsilon 1,2,\ldots..H+1$). Here motive is to maximize the network coverage time for that a routing matrix and optimal number of cluster required.

Average energy consumption for a cluster head of cluster head $\mathcal{CH}_p$ represented as E_p,

$$E_p=\mathcal{E}_{trns}\left(\sum_{1\leq q\leq H+1,q\neq p} d_{pq}\right)+\mathcal{E}_{rcv}\left(c_p+\sum_{1\leq q\leq H,q\neq p} d_{pq}\right)+\sum_{1\leq q\leq H+1,q\neq p} d_{pq}\,\mathcal{E}_{ar} \quad (3)$$

Where transmitter energy and receiver energy consumption are $\mathcal{E}_{trns}$ and $\mathcal{E}_{rcv}$ respectively. While $\mathcal{E}_{ar}$ is the loss of energy in air during transmission of data.

Considering equation (1) from physical layer information per bit received energy for considering distance between cluster head p and $q$as a_{pq} given as,

$$\mathcal{E}_{rpq}=\mathcal{E}_{tpq}P(a_0)\left(\frac{a_{pq}}{a_0}\right)^{-m}\varphi \quad (4)$$

The reliability of link to provide connectivity in the network is considered and for better network coverage. Received signal probability must follow the below equation (5).

$$PL\{\mathcal{E}_r>\delta\}\geq f_l \quad (5)$$

Where $\mathcal{E}_r$ is the received signal strength, δ predefined signal strength threshold value Result analysis and f_l is the link quality specifier.

Further For link reliability the Rayleigh channel model is considered. Based on signal probability, link quality specifier f_l determined as,

$$f_l=PL\{\mathcal{E}_{rpq}\geq\delta\}=PL\left\{\varphi\geq\frac{\delta}{\mathcal{E}_{tpq}P(a_0)}\left(\frac{a_{pq}}{a_0}\right)^m\right\}=e^{-\frac{\delta a_{pq}^m}{\mathcal{E}_{tpq}P(a_0)a_0^m}} \quad (5)$$

From equation (5) $\mathcal{E}_{tpq}$ can be represented as,

$$\mathcal{E}_{tpq}=-\frac{\delta}{\mathcal{E}_{tpq}P(a_0)a_0^m\log f_l}a_{pq}^m \quad (6)$$

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Further constant $-\frac{\delta}{\mathcal{E}_{tpq}P(a_0)a_0^m \log f_l}$ represented as α

$$\mathcal{E}_{tpq} = \alpha a_{pq}^m \text{ where } p \neq q. \quad (7)$$

Equation (3) can be simplified for p as,

$$E_p = \mathcal{E}_{rcv}\left(c_p + \sum_{1\le q\le H, q\neq p} d_{pq}\right) + \sum_{1\le q\le H+1, q\neq p} d_{pq}\left(\mathcal{E}_{trns} + \alpha a_{pq}^m\right) \quad (8)$$

Let suppose that initial residual energy of cluster head node $p$is Ei_p. For enhancing the maximum network coverage time optimization is needed, $p\epsilon 1,2,\ldots..H$ and hence,

$$\max\{C,R\}\min\left\{\frac{Ei_1}{E_1},\frac{Ei_2}{E_2},\ldots\ldots,\frac{Ei_H}{E_H}\right\} \quad (9)$$

Routing Approach

To enhance the network coverage time the routing techniques in WSNs is considered. Hop count is required between transmissions of data from source to destination. Meanwhile quality of link is also considered for the successful communication between transmitter and receiver and link quality factor is defined asf_l.

For transmission of data towards the base station a cluster head consider the closest $\mathcal{CH}$ as intermediator. A $\mathcal{CH}_p$ received the data from its own cluster member and other nearest cluster head, if $\mathcal{CH}_p$ also reside far from the base station then it forwarded the aggregated data to the $\mathcal{CH}_q$ and $\mathcal{CH}_p$ forwarded the aggregated data from its member and $\mathcal{CH}_p$ to the base station. Communication is processed using hop by hop inter clustering approach. Routing knowledge based clustering approach is considered for the shortest path communication and it minimize the energy consumption. The advantage of using the model over state of art approach is, it minimize communication overhead, minimize energy consumption of each node and improves coverage time which is experimentally proved in section 3.

III. EXPERIMENTAL RESULTS AND ANALYSIS

For the simulation study, Windows 10 with 64-bit operating system having CPU @ 2.90 GHz processor is utilized. This system having 1GB NVIDIA CUDA dedicated graphic card for better flexibility in UI related programs. A simulator is designed using .Net framework 4.0 and C# programming language is used. The performance of proposed approach is evaluated over exiting approach in terms of lifetime performance. The lifetime performance analysis is evaluated considering network coverage time, nodes death and communication overhead for varied node density. The result of the model is compared with existing base LEACH algorithm. Simulation parameter is shown in table1.

Parameter	***Value***
Sensor Node Energy	0.2j& 0.1j
Number of node considere	100,200,400
Network Area	25*25m
Data Transmission Speed	100 bits/ses
N/W Bandwidth	5000 bit/sec
Data Packet Size	2000 bits

Network Coverage considering First node death

In Figure 2, network lifetime performance for 100 sensor nodes considering initial energy of node as0.1j and lifetime analyze for 1st death of sensor for both proposed and existing system. It is observed that the first sensor death for existing system occurred after183 rounds. While for proposed system first death of sensor node occurred after 1236 rounds. A performance improvement of 85.19%is achieved for proposed model over existing model in term of lifetime considering first node death.

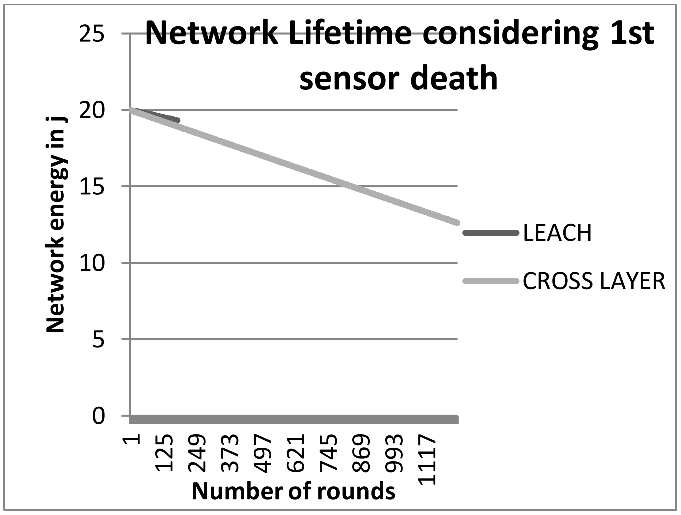

Figure 2 Network Lifetime of First Sensor Death

In Figure 3 time based simulation is consider for the proposed system performance analysis. System is simulated for 360sec and initial energy of node considered is 0.2j. Initial and remaining energy after simulation is analyzed for 100 nodes and it observed that the proposed system remaining energy is more than the existing system. Remaining energy percentage improvement of proposed system over existing system is 21.38%.

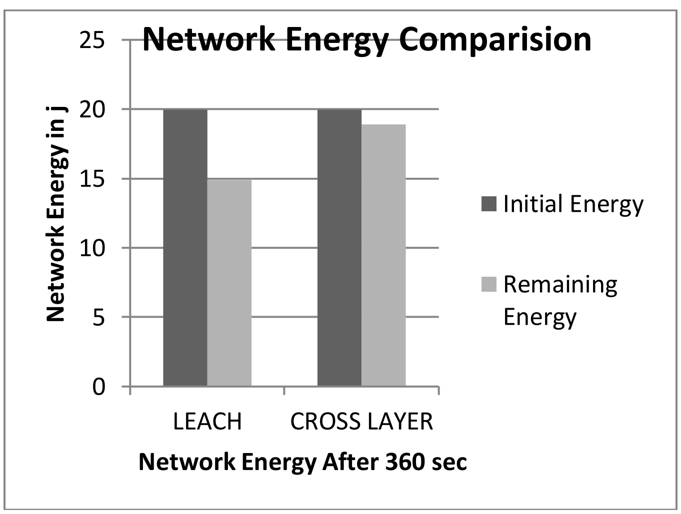

Figure 3 Energy Comparison considering Simulation Time

Network Coverage considering After 10% node death

Figure 4 represent the comparative analysis for 100,200 and 400 rounds and initial energy is consider as 0.1j. Existing system and proposed system network coverage performance are shown here. It is observed that number of rounds after 10% node death for both proposed and existing system. The sensor device is varied as 100, 200 and 400; an improvement of 30.18%, 46.9% and 82.26% is achieved by proposed mode over existing approach. From analysis it is observed that the as number of nodes is increased, the existing system performance decreased while proposed system performed well. This show the scalable performance of proposed approach interm of varied node density

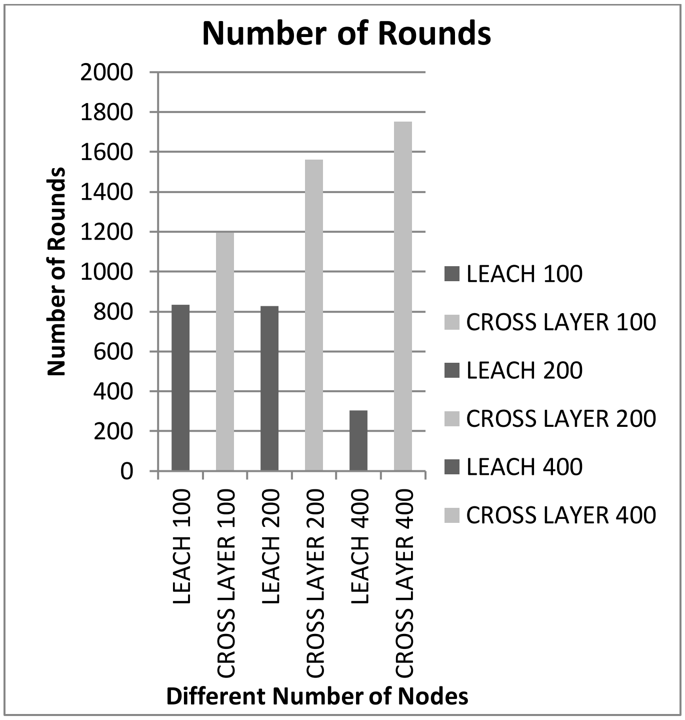

Figure 4 Network Coverage Comparison based on Rounds

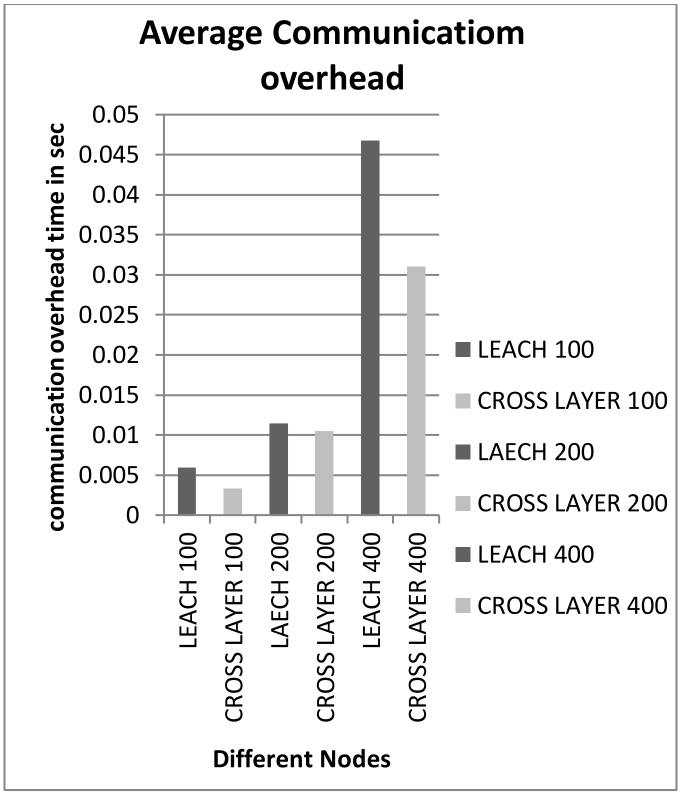

Figure 5 Network overhead Comparison

Average network communication overhead analyzed in Figure 5 considering 100, 200 and 400 nodes. As number of node is increased in the network, communication overhead also increased both proposed and existing approach. For 100 numbers of nodes existing system overhead is more than proposed system around 44.06%. For 200 numbers of nodes existing system overhead is more than proposed system around 9.09%. For 400 numbers of nodes existing system overhead is more than proposed system around 32.60%

IV. CONCLUSION

WSNs has versatile application, but network energy is the key issue in future applications which can be considered. Enhancement of network coverage time based on considering different layers. An Inter cluster communication based network design is considered here. Shortest routing path in inter-cluster communication for hop based communication is used for saving more energy in the network. Network performance is analyzed based on two network scenario. In first scenario the death of first sensor node is considered with initial energy as 0.2j and the remaining network energy performance in the network is presented. In second scenario different number of network size is considered as 100, 200 and 400 with initial energy as 0.1j. Network lifetime and communication overhead for both the proposed and existing system can be analyzed efficiently. Through result analysis it is analyzed that the proposed system performance is better than LEACH existing system. In future, routing matrix and the shortest path routing approach can be generalized.

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