A Cross-Layer based Energy Efficient Cluster Head Selection Model for Wireless SensorNetwork

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Abstract

Due to rapid growth of the wireless based application services; demand for wireless sensor networks WSN has increased that use battery more efficiently. In WSN enhancing the life span of network depends on the energy dissipation of the sensor devices. Reducing the energy dissipation of sensor devices will improve the lifetime and device failure which help in better connectivity and coverage of sensor network. There has been various approach that has been developed to improve energy efficiency of sensor network among that clustering is a significant technique that help in improving the network lifetime by reducing the energy consumption but the issues with existing methodology is the energy inefficiency in selecting the cluster head which result in loss of connectivity thus reducing the life time of network. To overcome this, the author proposes a cross layer design for cluster head selection based on connectivity of node. The experimental result shows that the proposed CL_LEACH perform better than existing LEACH in term of network lifetime, node decay rate and network communication overhead.

Keywords - *Wireless network, TDMA, radio channel measurement, cross layer.*

I. INTRODUCTION

In current era wireless network gain much attention. Research is ongoing day-by-day to improve more and more wireless technologies. WSN is a part of this technologies growth. These days remote correspondence turns out to be better known in every one of the fields, which offer ascent to change of W. . The W. offers a rich and multi disciplinary range of exploration connected to different applications such as military, healthcare, smart sensor based application for home and offices etc.. The fundamental prerequisites of an W. are availability, connectivity and coverage. The benefits of W. are self-organization, fault-tolerance and ease of deployment [1]. Difficulties of the W. are adaptability, energy dissipation, constrained capacity and transfer speed, survivability, battery lifetime. The WSN comprise of a substantial number of cost effective, low-control and smart sensor devices and an intermediate devices or the base stations (BSs) [2], [3]. These sensor devices are little in size and can perform numerous essential capacities, including object tracking, data preprocessing, and information correspondence [4], [5]. W. can be utilized in wide defense sector applications and other emergency situations [6], [7]. Because of different points of interest and their applicability and benefits, for example, simplicity of deployment, data transmission and self-association, W. have been supporting the conventional systems.

A WSN comprises of various little sensor devices spatially appropriated. The W. devices are outfitted with three noteworthy subsystems in particular sensory application with remote sensors, preprocessing the data in the subsystem with microcontroller and memory unit and imparting subsystems for transmitting the pieces of information between the sensor devices. All these are supplied by a battery source. In any case, general battery changing is badly designed because of the deployment nature of sensor devices is difficult to reach in area. An imperative viewpoint being developed of sensor hub is guaranteeing that there is constantly satisfactory energy available in the network [8]. Energy proficiency is a standout amongst the most essential outline components for the remote sensor systems, as the normal sensor hubs are furnished with restricted batteries. The transmission of information consumes the vast majority of the constrained hub's battery energy [9]. So there is need of energy effective routing methodologies to expand the system's lifetime. There are such a large number of approaches to lessen the energy utilization in sensor systems with the assistance of a few strategies and methodologies [10] [11].

The low energy adaptive clustering hierarchy LEACH strategy is a revolutionary protocol [12],[13]. The LEACH strategy forms many clusters of sensor devices and assign a cluster head (CH) node for each cluster, with the aim of reducing the energy depletion of WSN.A centralized approach of LEACH namely $LEACH-$,C where the base station takes the cluster formation decision using all composed information that provided better outcomes over the distributed approach in terms of the bandwidth utilization and lifetime of network[12].Recently many approach have been developed by enhancing the LEACH -C. In [14], each cluster head sensor devices avoids the energy exhaustion in its roles by assigning a vice-cluster head sensor devices in its cluster.LEACH in [15] considers the residual energy ofs the candidate cluster head sensor de vices more actively. In LEACH − CI [16] adopted a refined clustering technique based on K-mean clustering technique rather than simulated annealing [17] which is considered to be an effective clustering methodologies but still LEACH -C and its variant strategy have serious limits in practical applicability network deployment: (i) It induces unwanted signaling overhead at the base station to collect information in order to form a clustering of sensor device. (ii) Those methodology requires precise information about the sensor devices position which requires a added hardware such as global positioning systemGPS. (iii) Due to the temporal variation in network topography it is difficult to find the optimal cluster member and fitting it to positive number in existing strategy is considered to be suboptimal.(iv) The existing clustering strategy adopted so far consider energy dissipation of transmission link among cluster head and its cluster member only but fail to address the links among cluster head and the base station, which is an important factor in the formation of cluster. With these strategy depending upon the average based clustering where the center of a cluster is not essentially a cluster member. The resulting cluster head sensor devices elected among closer by member may not be the most effective.

There are various approach that has been developed recently to enhance lifetime of sensor network which is explained in section two and to overcome these shortcoming here the author propose a cross layer design for cluster head selection based on connectivity of sensor devices. Our method provide a cost effective solution by considering radio signal strength of sensor device for cluster selection and the message are broadcasted by using a TDMA based channel.

The paper organization is as follows: The literature survey is presented in section two. The proposed models are presented in Section three. The results and the experimental study are presented in the section four. The concluding remark is discussed in the last section.

II. LITERATURE SURVEY

There are have been several approaches that have been proposed in recent time in order to improve the lifetime efficiency of wireless sensor network which are surveyed below.

In [18] they proposed a dynamic cluster head selection method (DCHS for W. . They addressed the sensor network coverage and energy efficiency of sensor devices. They used voronoi diagram to find the cluster head. Their method improves in reducing the data redundancy during transmission and also reduce energy dissipation of sensor devices and also addresses the disproportion of the energy consumption and extending the life time of the network. The lifetime of network is improved by over 50% for LEACH , and improved by 30% also the survival time of the network is longer than that of Energy-balanced deterministic clustering algorithm and adaptive energy optimized clustering algorithm achieving the effectiveness of the network energy consumption, and it has the longest network life time.The re-division of the monitoring area after the death of all the redundant nodes under the same coverage area is not considered here.

In [19] proposed a new low-energy adaptive clustering hierarchy strategy for WSN that adopts a distributed formation of clustering strategy based on affinity propagation Their modified strategy based on LEACH methodology namely (LEACH − A. allows a completely distributed control and addresses practical limitations of conservative LEA(based strategies by reducing the hardware cost since it does not require any hardware such as G and simplifying network functionalities. Their experimental outcomes shows that their approach significantly achieves better performance than existingLEACH based strategies in terms of energy decay rate, through put and network lifetime.

In [20] Fuzzy c-means (FC is a centralized strategy for cluster formation that use residual energy and sensor device location to choose the cluster head. It allocates a degree of belonging to every sensor devices for every cluster head rather than being a cluster member of a cluster. This methodology protocol adopts F(algorithm in order to form cluster that aid in minimizing the spatial distance between the devices which in turn aid in forming a good cluster.The cluster formation is performed by minimizing an objective function, which consists of the degree of belongingness and the distance among the sensor devices and center point of the cluster.The principle used here is based on fuzzy logic in order to obtain the degree of belongingness after it has been calculated. Once the completion of first phase of clustering and data transmission, the present cluster head select a new (for next phase which depends upon the energy received from every sensor device. The F(strategy is an efficient way to distribute the sensor devices and the load of the network among the clusters. The experimental result shows the F(approach achieves better energy efficiency and improved the overall lifetime of network since the mean distance of every sensor device to cluster head is minimized which aid in optimizing the transmission power of non-cluster head sensor devices.

In [21] the proposed a three-layer LEACH TL_LEACH in order to reduce the sensor devices which communicates with the base station directly and it could save unnecessary power consumption. The TL-LEACH to extension the original two-layer LEACH to a three-layer clustering architecture. The sensory information is transmitted from the layer-0 sensor devices to the layer-1 , then on to the layer-2 , and finally to the base station in layer-3.During the set-up stage, the selection of layer-1 cluster head is same as toLEACH Nevertheless these selected cluster head cannot communicate with base station directly. Once the layer-1 cluster head are selected, many layer-2 cluster head are further chosen from the layer-1 cluster head based on their residual energy for transmitting packet to the base station. Information from other layer-1 cluster head will be fused in these layer-2 cluster heads and then be communicated to the base station. Thus, a three-layer organization consists of layer-0 sensor devices, layer-1 cluster heads, layer-2 cluster head, and the base station. The experimental result show that their approach show a great improvement on lifetime efficiency as compared with the existing methodology.

In [22] they proposed a hybrid hierarchical clustering approach by adopting a centralized gridding for the upper-level head selection and distributed clustering for the lower-level head selection. Their approach balances the communication load on sensor devices and increases the network lifetime and scalability. The experimental outcomes shows that their approach achieve better efficiency than other distributed algorithms. Therefore, the methodology is suitable for large-scale WSN

It is seen from literature that the existing methodology to improve the energy efficiency of WSNis not efficient and suffers from high overhead for cluster selection and increase data transmission latency and data redundancy due to its cluster formation hierarchy. To overcome these here the author propose a cross layer design for cluster head selection based on connectivity of sensor devices. Our method provide a cost effective solution by considering radio signal strength of sensor device for cluster selection and the message are broadcasted by using a TDMA based channel. The proposed modified LEACH based on cross layer model is presented in next section below.

A. *Proposed Cross Layer Model*

Here the author adopts cross layer design for better cluster selection that aid in improving network node connectivity and improve lifetime of network. The proposed model is compared with existing *LEA* based clustering protocol. The basic architecture of the proposed cluster formation is shown below

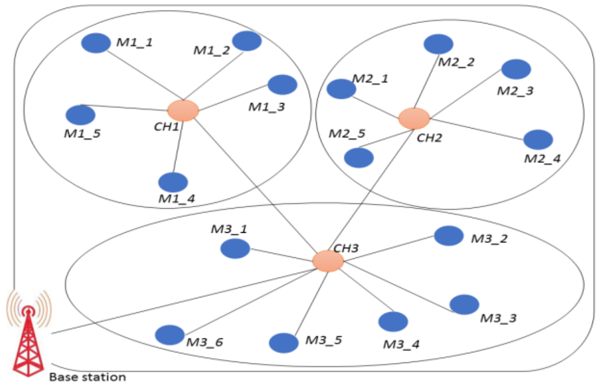

Figure 1: The Architecture of Proposed Cluster Formation

In LEACH protocol each and every sensor devices serve as cluster head in round based on a random and unbiased manner. The LEACH protocol is further divided into multiple rounds of fixed time duration and each round is divided into two stage and they are as follows the setup stage and the steady stage. In setup stage certain devices are chosen to behave as cluster heads by adopting a distributed strategy performed in every device. Consequently, the clusters equivalent to those chosen as cluster head are organized. In steady stage every device performs the sensing activity and generate the data and it is forwarded to the corresponding cluster heads and then the cluster head transmit this data to the sink or base station.

Selection of clusterhead in LEACH is as follows. In every round, for a particular sensor device a random uniform value between 0 and 1 is obtained and the obtained value is compared with the threshold H(d) of corresponded to this sensor devices. If the obtained value is less thanH(d), then this sensor devices elect himself as cluster-head in that particular round and the value of the threshold is updated in each and every round.

$$H(d) = \begin{cases} \frac{r}{1 - r \times [\varphi mod(1/r)]}, & if\ d \epsilon S; \\ 0, & Otherwise. \end{cases} \qquad (1)$$

Where r represent mean ratio of cluster head in every round to the total sensor devices, $\varphi, 0 \leq \varphi < 1$ is the current round number, and is the collection of sensor devices that has not elected as cluster head of period 1 rounds, that is, rounds $0 \sim 1/r$ -, rounds $1/r \sim 2/r - 1$ and so on. Based on the equation (1) every sensor devices behaves as CH for a particular period in a round. In the next round this sensor devices is removed for cluster head selection candidate.

B. Cross Layer Based System Channel Modelling

The sensor device radio transmission energy dissipation is directly associated to the considered propagation model. The propagation model considered here can be expressed as follows

$$M(l) = M(l_0) + 10\alpha\log_{10}(l/l_0) \quad (2)$$

Where the radio propagation loss which are measured in DB (decibel watt) at a distance l is represented by, $M(l)$ where l represent distance among receiver and the transmitter, α represent the path loss parameter and $M(l_0)$ is radio propagation loss at l_0 reference distance. The author consider that there are K devices of sensor placed in a sensing field of area . The author consider a random deployment of sensor nodes with in its area limit which employ a routing strategy to forward the sensed data to the base station which is placed outside the region of sensing area. The sensor device are considered to be homogeneous in nature which has same energy and sensing range (therefore the sensing area is πP^2 Here the author considers a first order energy consumption model as in figure 2. From figure 2 the ϵ_{amp} represent the energy requirement of transmitter power amplification to transmit a bit to the receiver at distance l = 1and D_{elec}denotes the energy required to handle trans-receiver circuitry which is measured in nano joule. Therefore the energy requirement of transmitting j message bit to a distant l receiving device can be evaluated considering equation (2) is as follows

$$D_{H_x}(j,l) = j(D_{elec} + \varepsilon_{amp} l^{\alpha}). \quad (3)$$

The energy required to obtain a bit of data by the receiver is as follows

$$D_{P_x}(j) = jD_{elec}. \quad (4)$$

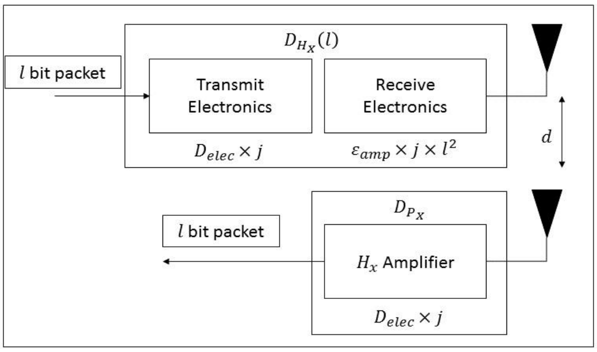

Figure 2: First Order Energy Model

C. Modeling Overlapping Area of Sensor Devices for Cluster Head Selection

Generally the sensor devices are deployed in a random manner over the entire area for various applications; therefore there exist an overlapping region of the sensing areas of different sensor devices. Then the sensor device density of a local area is significantly lower than mean, than a target location is covered by only one sensor device and similarly when a local areais significantly higher than mean sensor device density, a target location may be covered by several sensor devices. Therefore in order to obtain two overlapping Θ_F sensor device with distance p apart 0≤P≤2P is estimated using a geometric theory of intersection of two circle which is as follows.

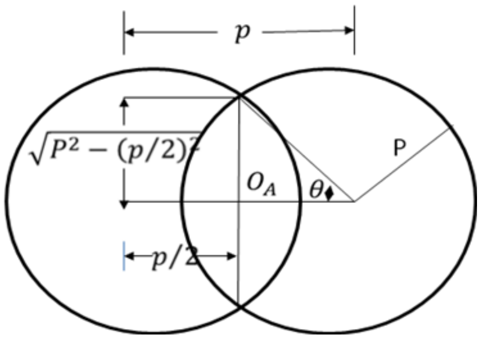

Figure3: Overlapping Area of Sensor Devices

$$O_F = 2P^2\left[\theta - \frac{p}{2P}\sqrt{1-\left(\frac{p}{2P}\right)^2}\right], \quad (5)$$

Where $\theta = \cos^{-1}(p/2\text{P})$ To obtain a normalized overlapping w of sensor device in a network is as follows

$$\omega = O_F/\pi P^2 = 2\left[\cos^{-1}(r) - r\sqrt{1-r^2}\right]/\pi \quad (6)$$

Where $0 \leq r \leq 1$ and $r = p/2\text{P}$ and value of w is in range of 0 and 1

To enhance the cluster head selection and to improve network lifetime by better network coverage different sensor device are assigned different likelihood of being cluster head and to calculate this likelihood it depend on the normalized active sensing coverage area of sensor devices. The active sensing region is represented as the ratio of active sensing coverage region to the maximum sensing region of a sensor device. Let consider a sensor device that $\mu_{0\%}$ of this sensor devices area of sensing is enclosed by this sensor device only and out of that μ_n %of this sensor devices area of sensing is enclosed by this sensor device and apart other n adjacent sensor devices. Now let consider an instance that μ_3 % of an sensor devices area of sensing enclosed by 4 sensor devices that include this sensor device and out of other 3 adjacent devices. Therefore the normalized active sensing region of this sensor device is represented by following equation

$$\mu = \mu_0 + \sum_{n=1}^{\infty} \frac{\mu_n}{n+1}. \quad (7)$$

The assessment of μ is in between $(0,1)$ If the area of sensing of a sensor device is overlapped by many sensor devices the assessment of μ is less than 1 where as for the non-overlapped with any other device than the assessment of μ is equal to 1. But estimating number of neighboring devices by the sensor device is not practical due the battery resource constrained of sensor device. To address this here the author uses the signal strength transmitted by these adjacent sensor device therefore the mean signal strength received from the adjacent sensor devices is used to compute the normalized active sensing area of a sensor devices by computing there equivalent distance. Once the deployment of sensor devices done every sensor device transmits a hello message to their adjacent sensor device in order to detect their neighbor. The power required to transmit this hello message is computed as follows

$$R_h = R_{sen} + M(2P), \quad (8)$$

Where M(2P) denotes the radio propagation loss at the distance of 2P and R_{sen} denotes the radio receiver sensitivity. This result in only the sensor device that are within 2P will receive the hello message and the non-overlapped sensor will not receive the hello message and this procedure is done only once to predict the normalized active area of sensing.

Consider a sensor device d that received hello message with received radio signalstrength R_n for $n = 1,2,3, \dots$. The mean signal strength received R_p of sensor device is computed as follows

$$R_p = 10\log_{10}\left[\sum_{n=1}^{D} 10^{R_n/10}/D\right]. \quad (9)$$

The adjacent sensor devices of sensor device d are computed as an device with distance p to a sensor device d. The equation (8) can be written as follows

$$R_h = R_p + M(\bar{P}) = R_{sen} + M(2P).$$

Then considering the propagation model in equation (2) we have corresponding distance p as follows

$$\bar{p} = 2P \times 10^{[R_{sen} - R_p]/10\alpha}. \quad (11)$$

Consequently by using equation (6) and when $r = \bar{p}/$ 2P, we obtain the normalized overlapping region w(d) for sensor device d . Then based on equation (7) the normalized active area of sensing is as follows

$$\mu(d) = \mu_0 + \frac{\mu_1}{2} = [1 - \omega(d)] + \frac{\omega(d)}{2} = 1 - \frac{\omega(d)}{2} \quad (12)$$

From the above equation it can be assured that a sensor device with smaller value of μ(d) is been given higher likelihood of being cluster head and similarly for larger μ(d) is been given the smaller likelihood of being cluster head. Therefore the LEACH threshold selection in equation (1) and the parameter r is changed to be parameter proportional to a sensor devices normalized overlapping region, i. e. a particular sensor device d , we obtain the following value as follows

$$r(d) = \propto \times\, \omega(d), \quad (13)$$

Where α depict the mean amount of cluster head. Now the proposed threshold H(d) considering sensor device d can be rewritten as follows

$$H(d) = \begin{cases} \frac{r(d)}{1 - r(d) \times [\varphi mod(1/r(d))]}, & if\ d \in \bar{S}; \\ 0, & Otherwise. \end{cases} \quad (14)$$

Where S is a collection sensor devices that has not yet been as a cluster head in the present round of period, is the sensor node that behave as cluster head in round $1/r($. d) Based on this every sensor devices are selected to be cluster head with varied likelihoods.

The sensor device with a large quantum of $\mu($is been given smaller likelihood of being cluster head were as a sensor device with small $\mu($d) is given higher value of $r($ d) that is given as input in equation (14) and the sensor device will behave as cluster head for a short period of time. Subsequently the sensor devices the higher $\mu($ d)will aid in improving energy efficiency due to being cluster head, however the smaller value $\mu($ d)sensor device will carry the burden of being cluster head. From this it seen that the proposed cluster selection strategy based on normalized active sensing range improved the network lifetime and its coverage since the sensor device with smaller normalized active sensing range dies first. The simulation and experimental proof of proposed methodology is proved in next section below.

III. SIMULATION RESULT AND ANALYSIS

The system environment used is windows 10 enterprises 64-bit operating system with 12GB of RAM. We have used sensoria simulator which is a dot net based simulator that uses C# as a programming language. We have conducted simulation study on following parameter for network lifetime and communication overhead and compared our proposed $CL - LEA$ with existing LEAbased protocol and we have varied node size by 500, 750 and 1000 and conducted simulation study and the simulation parameter are shown in below table 1 below.

Table I Simulation Parameter Considered

Network Parameter	***Value***
Network Size	***30m * 30m***
Number of sensor nodes	***500, 750, 1000***
Number of Base station	***1***
Initial energy of sensor nodes	***0.1 J***
Radio energy dissipation	***50 nj/bit***
Data packet processing delay	***0.1 ms***

In Fig. 4, 5 and 6, we can see that the proposed $CL - LEA$ clustering technique performs better than the existing LEAalgorithm in term of network lifetime efficiency. The experimental result shows that the energy efficiency of the proposed $CL - LEA$ algorithmover the existing LEA.The proposed $CL - LEA$ improves the lifetime of sensor network by over 89.423%, 90.57% and 92.585% when sensor node equal to 500, 750 and 1000 respectively over LEA . From the experimental result we can see that when we increase the sensor node the performance of proposed $CL - LEA$ get better but the performance of LEA protocol decreases with increasing number of nodes which is shown in figure 7.

In Fig. 8 we can see that the proposed $CL - LEA$ clustering performs better than LEA in term of node decay rate. The experimental result shows that the node decay rate of LEA increases when we increase the number of node to 500, 750 and 1000 and the node decay rate performance our proposed $CL - LEA$algorithm is comparatively low when compared to LEA when node is increased to 500, 750, 1000.The proposed $CL - LEA$ reduces the node decay rate of network by over 75.67%, 81.57% and 88.11% when sensor node equal to 500, 750 and 1000 respectively. From this we can conclude that the proposed $CL - LEA$ clustering performs better than LEA in term of node decay rate. In Fig. 9 we can see that the proposed $CL - LEA$ clustering performs better than LEA in term of network communication overhead. The experimental result shows that the communication overhead of LEA increases when we increase the number of node to 500, 750 and 1000 and the communication overhead performance our proposed $CL - LEA$algorithm is comparatively low when compared to LEA when node is increased to 500, 750, 1000.The proposed $CL - LEA$ reduces the communication overhead of network by over 74.30%, 86.96% and 91.42% when sensor node equal to 500, 750 and 1000 respectively. From this we can conclude that the proposed $CL - LEA$ clustering performs better than LEA in term of network communication overhead.

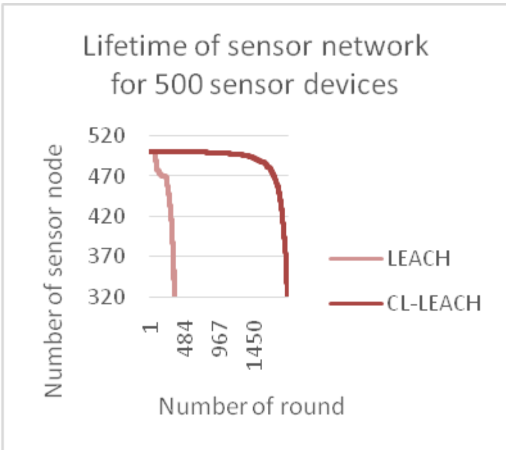

Fig. 4.Network Lifetime Analysis For 500 Sensor Devices

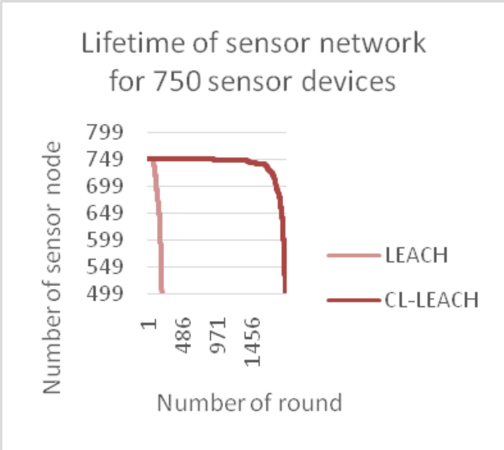

Fig. 5.Network Lifetime Analysis for 750 Sensor Devices

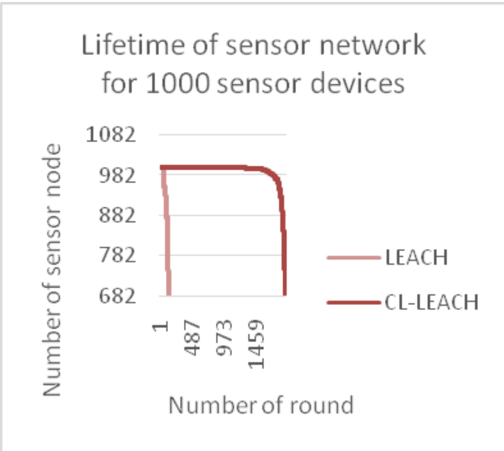

Fig. 6.Network Lifetime Analysis for 1000 Sensor Devices

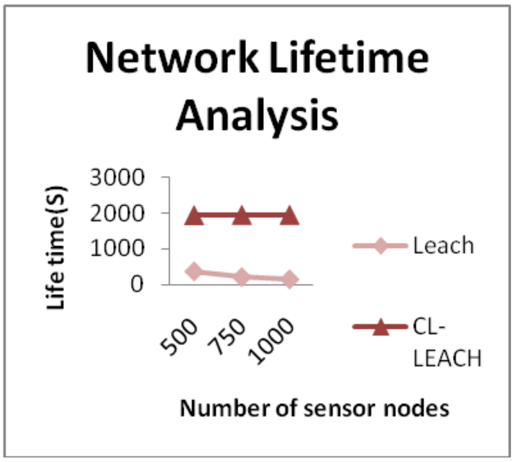

Fig. 7.Network Lifetime Analysis for Varied Sensor Devices

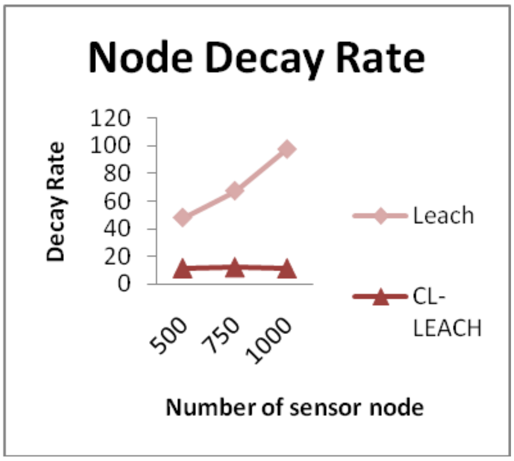

Fig. 8.Sensor Node Decay Rate

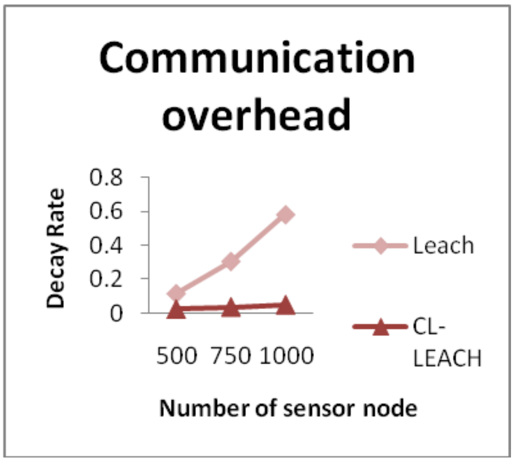

Fig. 9.Communication Overhead

IV. CONCLUSION

Enhancing the life span of WSN depends on the energy dissipation of the sensor devices. Reducing the energy dissipation of sensor devices will improve the lifetime and device failure which help in better connectivity and coverage of sensor network. The existing clustering protocol based on $(LEAC$ is not efficient and suffers in term of life time of network so there is a necessity for new clustering protocol to increase network lifetime. Here the author proposed a cross layer based clustering protocol namely $CL - LEA$ to improve energy efficiency of sensor network. Our proposed $CL - LEA$ algorithm improved lifetime of wireless sensor network by over 89.423%, 90.57% and 92.585% over LEA when sensor node equal to 500, 750 and 1000 respectively,the node decay rate performance is reduced by 75.67%, 81.57% and 88.11% over LEA when sensor node equal to 500, 750 and 1000 respectively, and the network communication overhead performance is reduced by 74.30%, 86.96% and 91.42% over LEA when sensor node equal to 500, 750 and 1000 respectively. Experimental results show that the proposed $CL - LEA$ performs better than LEACH in term lifetime efficiency, node decay rate and network communication overhead. In future work we would conduct simulation study to check the performance of other network parameter such as packet delay by varying node and check how the proposed protocol perform by varying the simulation area size and also propose a packet failure probability for better usage of channel thus will aid in improving the life time of network.

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