Global Journal of Computer Science and Technology
Network, Web & Security
Volume 13 Issue 4 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Enhancing Network Lifetime in Wireless Sensor Networks Adopting Elephant Swarm Optimization

By Chandramouli.H, Dr. Somashekhar C Desai, K S Jagadeesh & Kashyap D Dhruve

JJT University, Jhunjhunu

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GJCST-E Classification : C.2.1

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Chandramouli.H [α], Dr. Somashekhar C Desai [σ], K S Jagadeesh [ρ] & Kashyap D Dhruve [ω]

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I. Introduction

Let us consider a topology of wireless sensor networks deployed over a specified geographical region. The sensor nodes are assumed to have homogenous energy properties and are battery operated which is the case most often than not. The sensor distribution over the geographical region is considered to be dense to achieve higher transmission data rates. Owing to dense deployments numerous links are established induce interference amongst the sensor nodes which needs to be minimized to achieve better network performance in terms of throughput. This paper introduces an Elephant Based Swarm Optimization model to enhance network life time. A cross layer approach is adopted to incorporate the elephant swarm optimization features.

Elephants are social animals [1] and exhibit advanced intelligence [2]. Elephants are often found to exist in a "fluid fission-fusion" social environment [3]. Elephants characterized by their good memory, their nature to coexist and survive within a "clan" [4] (a large swarm of more than 1000 elephants) socially formulated during testing times like migration and when the resources are scare. Elephants exhibit an unselfish behavior which enable them to grow and is the secret of their longevity. Keeping progress and survivability in mind the older elephants disassociate from the "clan". Elephants by nature are protective of their younger generation. Elephants communicate using varied advanced techniques which include acoustic communication, chemical communication, visual communication and tactile communication [5] [6]. Their memory empowers them with recognition, identification and problem solving scenarios [4]. All these features exhibited have influenced the authors to incorporate such behavior in wireless sensor networks to improve network performance.

The elephant swarm model is complex and to realize such behaviors in wireless sensor networks the authors have proposed to adopt a cross layer approach to incorporate the elephant swarm model. Optimizations need to be adopted at the Routing Layer, MAC Layer and the Radio Layer of the wireless sensor node. This paper introduces a cross layer approach to incorporate the elephant swarm optimization technique which is compared with the popular $LEACH$ protocol and its efficiency is proved in the latter section of this paper.

The remaining manuscript is organized as follows. Section two discusses a brief literature study conducted during the course of the research work presented here. The system modelling and the elephant swarm optimization technique using a cross layer approach is discussed in the third section of this paper. The experimental study conducted is described in the penultimate section of this paper. The conclusions drawn and the future work is presented in the last section of this paper.

II. Literature Review

The literature review discussed in this paper emphasizes the cross layer architectures proposed by researchers to overcome the drawbacks that exist in wireless sensor networks.

A research work [7] describes the fundamental concept of sensor networks which has been made viable by the convergence of micro electro-mechanical

Author α : Research Scholar, JJT University, Jhunjhunu, Rajasthan, India. E-mail : hcm123cool@rediffmail.com
Author σ : Professor, BLDEA College of Engineering, Bijapur, India. E-mail : desaisc07@gmail.com
Author ρ : Research Scholar, JJT University, Jhunjhunu, Rajasthan, India. E-mail : Ksj_20012002@yahoo.co.in
Author ω : Technical Director, Planet-I Technologies, Bangalore, India. E-mail : kashyapdhruve@hotmail.com

systems technology, wireless communications and digital electronics. In their work initially the potential sensor networks are explored and then the dominant factors influencing the system architecture of network is obtained and in the later stage the communication architecture was outlined and the algorithms were developed for different layers of the network for system optimization. As this proposal brought certain positive results but was lacking the optimized output and having a lot of vacuum for further development.

The researcher in [8] developed a recommender system, employing a particle swarm optimization (PSO) algorithm for learning the personal preferences of users and facilitates the tailored solutions. The system being used in this research was based on collaborative filtering approach, building up profiles of users and then using an algorithm to find profiles similar to the current user. To overcome the problem of sparse or implicated data they utilized stochastic and heuristic-based based models to speed up and improve the quality of profile matching and finally the PSO was used to optimize the results. That system was found to be outperforming Genetic Algorithm concept but the system could not play a vital role in higher data rate with cross layer architecture and especially for heterogeneous type of network.

In literature [9] a number of fundamental cross layered resource allocation techniques at MAC layer were considered for fading channel. This research work emphasizes on characterization of fundamental performance limits while considering the network layer, MAC layer quality and physical layer as performance.

Considering the dominant network parameters like deploy, energy consumption, expansibility, flexibility and error tolerance Jin, Lizhong et al [10] presented a research work that employs a cross layer MAC protocol for wireless network. This work employs the splitting of MAC layer and of course it performed well, but considering the higher data rate transmission this system was found to be ineffective even having more error prone.

In [11] investigated the cross layer survivable link mapping when the traffic layers are unambiguously desired and survivability is must. In this work a forbidden link matrix is identified the masking region of the network for implementing in such conditions where some physical links are reserved exclusively for a designated service, mainly for the context of providing multiple levels of differentiation on the network use. The masking upshot is then estimated on two metrics using two sensible approaches in a real-world network, depicting that both effectiveness and expediency can be obtained.

The literature [12] the researcher proposed a route discovery and congestion handling mechanism that employs a cross layer model including a potential role in congestion detection and its regularization. The limitation of the proposed technique was its confined data rate.

Hang Su [13] proposes the cross layer architecture based an opportunistic MAC protocol that integrates the spectrum sensing at PHY layer and packet scheduling at the MAC layer. In their proposal the secondary user is equipped with two transceivers where one is tuned for dedicated control channel while another one is designed particularly for cognitive radio that can effectively use the idle radio. They propose two shared channel spectrum-sensing approach, named as the random sensing policy and the negotiation-based sensing policy so as to assist the MAC protocols detect the availability of leftover channels. This technique has a great potential but the emphasis has been made on the efficient use of leftover frequency and thus the other QoS parameters are not being considered.

In literature [14] proposed a new cross layer-based MAC protocol stated as $CLMAC$. In this proposed cross layered MAC technique, the communications among MAC, Routing and Physical layers are fully exploited so as to minimize the energy consumption and multi-hop delay of the data delivery for wireless sensor networks. In precise, in that approach the carrier-sensing technology is applied at the layer so as to sense the traffic load and necessarily initiates the neighbor nodes in multi hops so that the data transmission can be realized over multi hop. Similarly, by implementing the routing layer information, the developed cross layered facilitates the receiver of the ascending hop on the path of routing that has to be effectively waken up and ultimately it results into the potential reduction in energy consumption.

In reference [15] the $LEACH$ (Low Energy Adaptive Clustering Hierarchy) routing protocol which is a conventional clustering communication protocol has been implemented. The proposed protocol is dominantly used in WSN. Then while there are certain limitations in LEACH, in as the nodes consume a lot of energy and the efficiency of nodes ultimately decreases because the nodes which are having low energy and are at remote from Base Station become the cluster head nodes. This work analyzes the energy model and considers three important factors: The energy for individual nodes, the number of times that the node is chosen as cluster heads and the distances between nodes and BS. In this research work the author changes the threshold function of the node so as to extend the lifetime of the network and to achieve the goal of balancing the energy of the network. This work has indicated that the implemented system can of course prolong the life span of the network, but the drawback of this work is that it does not consider the other network optimization problems like, throughput, delay, overheads etc.

The techniques incorporated by researchers to enhance the network lifetime of wireless sensor networks is also considered during the course of the research presented here [16] [17] [22].

III. Elephant Swarm Optimization in Wireless Sensor Networks

a) System Modeling of Sensor Networks

In this section of the paper the system modelling adopted to realize the elephant swarm optimization for wireless sensor networks is discussed.

Let us consider a w wireless sensor nodes represented by a set W which constitute a static network defined as

$$W = \{w_1, w_2, w_3, \dots . w_w\}$$

In the considered network W, the wireless communication links that exist between two nodes $w_1 \in W$ and $w_2 \in W$, a relatively high transmission power allocation scheme is considered . The high power allocation scheme causes the higher power consumption that ultimately results into numerous interferences situation between other nodes as well as degraded network life time and hence poor efficiency. The communication channel being considered over the links is nothing but Additive White Gaussian Noise ($AWGN$) channel having confined noise power level. Here, one more factor called deterministic path loss model has been assumed. If the signal to noise ratio of a communication link is represented by γ then the maximum data rate supported (m_r) per unit bandwidth is defined as

$$m_r = log\big(1 + (B \times \gamma)\big)$$

Where

$$B = \frac{-1 \cdot 5}{log(5BER)}$$

This considered model can be realized using modulation schemes like $MQAM$. The constellation size for the $MQAM$ is ≥ 4 and varies with time over a considered link [23]. The model assumes a $TDMA$ scheduling system of communication between the nodes. The model considered assumes that there exists N_t time slots for the medium access control layer (MAC) and a unique transmission mode is applicable per slot.

Let us consider that a particular node $w_w \in W$ transmits at a power level $\mathrm{P_t}$ then the power consumption of the amplifier is defined as

$$(1 + \alpha)\mathrm{P_t}$$

Where α is the efficiency of power amplifier and $\alpha > 0$ to achieve the desired signal amplification.

A homogenous sensor network model is considered $i.e. \forall\, w_w \in W :\ \alpha_1 = \alpha_2 = \cdots = \alpha_w$.

The directed graph that represents the network W under consideration, is defined as

$$D_g = (W\ L)$$

Where indicates set of directed links.

Let $\mathcal{A} \in \mathcal{R}^{|W| \times |L|}$ indicates the incidence matrix of the graph D_g then we can state that

$$\mathcal{A}(\mathrm{w}_w, \ell) = \begin{cases} -1 & \mathit{If}\ \mathrm{w}_w \text{ is the receiver of link } \ell \\ 0 & \mathit{in\ other\ cases} \\ +1 & \mathit{If}\ \mathrm{w}_w \text{ is the transmitter of link } \ell \end{cases}$$

We present an expression

$$\mathcal{A} = \mathcal{A}^+ - \mathcal{A}^-$$

Such that $\mathcal{A}^+(v,\ell), \mathcal{A}^-(v,\ell) = 0$, $\mathcal{A}^+$, $\mathcal{A}^-$ and have the entries of 0 and 1.

As discussed N_t is the number of time slots in individual frame of the periodic schedule. L^{n_t} represents the set of link scheduled. These are allowed to transmit during time slot defined as

$$n_t \in \{1, \cdots\cdots\cdots, N_t\}$$

$P_l^{n_t}$ and $m_{r_l}^{\ n_t}$ represents the power of transmission and per unit bandwidth rate respectively over link l and n_t slots. The vectors of the time slot n_t are $m_r{}^{n_t}$ and $P^{n_t} \in \mathcal{R}^{|L|}$. P_ℓ^{max} is the maximum limit of allowable transmission power for the node which belongs to link. The analogous vector is $P^{max} \in \mathcal{R}^{|L|}$. The vectors $1_t(P^{n_t})$ id defined as

$$\big(1_t(P^{n_t})\big)_{w_w} = \begin{cases} 1 & if\ \big((\mathrm{e}_v^+)^T \times P^{n_t}\big) > 0 \\ 0 & In\ other\ cases \end{cases}$$

Where $(\mathrm{e}^+)^T$ is the v^{th} row of the matrices $\mathcal{A}^+$. Also $\big(1_t(P^{n_t})\big)_{w_w} \in \mathcal{R}^{|W|}$

The vector $1_{m_r}(P^{n_t})$ is defined as

$$\big(1_{m_r}(P^{n_t})\big)_{w_w} = \begin{cases} 1 & if\ \big((\mathrm{e}_v^-)^T \times P^{n_t}\big) > 0 \\ 0 & In\ other\ cases \end{cases}$$

where $(\mathrm{e}_v^-)^T$ is the v^{th} row of the matrices $\mathcal{A}^-$. Also $\big(1_{m_r}(P^{n_t})\big)_{w_w} \in \mathcal{R}^{|W|}$.

The initial homogenous energy of all the nodes $w_w \in W$ defined as $\mathcal{E}_{w_w}$ and the energy $\mathcal{E} \in \mathcal{R}^{|W|}$.

Let P_{tcon} represents power consumption of transmitter and P_{rcon} represents the power consumption of the receiver and is assumed to be homogenous for all the nodes. The consumed by each node $w_w \in W$ is $\leq \mathcal{E}_{w_w}$.

Let the sensing events that are induced in the network induce an information generation rate represented as $\mathcal{S}_{w_w}$. It can be stated that $\mathcal{S} \in \mathcal{R}^{|W|}$ represents a vector which constitute of $\mathcal{S}_{w_w}$.

The data aggregated at the sink is defined as

$$\mathcal{S}_{Sink} = -\sum\nolimits_{w_w \in W, w_w \neq Sink} \mathcal{S}_{w_w}$$

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The link gain matrix of the wireless sensor network considered is defined as

$$D_g = \mathcal{R}^{|L| \times |L|}$$

The power from the transmitter of the $\mathcal{K}^{th}$ link to the receiving node on link ℓ is represented as $D_{g_{l\mathcal{K}}}$ and $\mathcal{N}_0$ represents the total noise power over the operational bandwidth.

The T_{w_w} represent the network lifetime when a percentage of nodes $w\%$ runs out of energy. This is a common criterion considered by researchers to evaluate their proposed algorithms [16] [17].

The maximum data rate supported for transmission over a particular Link $l \in L$ is defined as

$$(1 + (\mathcal{K} \times log(SINR)))$$

b) Problem Formulation

A cross layer approach is adopted to enhance the network lifetime of the wireless sensor network. Elephants are social animals and are said to possess strong memory of the events that occur.

The problem of optimizing or maximizing the life span of the network can be presented as a function defined as follows

$$max.(\mathcal{T}_{net})$$

$$i.e.\ \frac{1}{N_t}\mathcal{A}(m_r{}^1 + \cdots\cdots + m_r{}^{N_t}) = \mathcal{S}$$

$$log\left(1 + \mathcal{K}\frac{D_{g_{ll}}\mathcal{P}_\ell^n}{\sum_{\mathcal{K}\neq\ell} D_{g_{lk}}\mathcal{P}_k^n + \mathcal{N}_0}\right) \geq m_{r_l}{}^{n_t}$$

The maximization function $max.(\mathcal{T}_{net})$ can be defined as

$$\frac{\mathcal{T}_{net}}{N_t}\sum_{n_t=1}^{N_t}\left((1 + \alpha)\mathcal{A}^{+}\mathcal{P}^{n_t} + P_{tcon}1_t(\mathcal{P}^{n_t}) + P_{rcon}1_{m_r}(\mathcal{P}^{n_t})\right) \preccurlyeq \mathcal{E}\, m_r{}^{n_t} \succcurlyeq 0, 0 \preccurlyeq \mathcal{P}^{n_t} \preccurlyeq \mathcal{P}^{max}$$

For all time slots $n_t = 1, \cdots\cdots, N_t$ and $l \in L$, the constituting variables are $\mathcal{T}_{net}, m_{r_l}{}^{n_t}, \mathcal{P}_\ell^{n_t}$, for a set $n_t \in \{1, \cdots\cdots, N_t\}, l \in L$.

Let us define a variable O such that

$$O = (\mathcal{T}_{net})^{-1}$$

The elephant swarm optimization is applied to attain minimized function defined as

$$min.(O)$$

$$i.e.\ \mathcal{A}(m_r{}^1 + \cdots\cdots + m_r{}^{N_t}) = (\mathcal{S} \times N_t)$$

$$log\left(1 + \frac{D_{g_{ll}}\mathcal{P}_\ell^{n_t}}{\sum_{\mathcal{K}\neq\ell} D_{g_{lk}}\mathcal{P}_k^{n_t} + \mathcal{N}_0}\right) \geq m_{r_l}{}^{n_t}$$

The minimization function or the elephant swarm optimization objective $min.(O)$ can be defined as

$$\sum_{n^t=1}^{N_t}\left((1 + \alpha)\mathcal{A}^{+}\mathcal{P}^{n_t} + P_{tcon}1_t(\mathcal{P}^{n_t}) + P_{rcon}1_{m_r}(\mathcal{P}^{n_t})\right) \preccurlyeq O\, \mathcal{E}\, N_t$$

The model presented here considers $TDMA$ based MAC systems the minimization function can be defined as

$$min.(O)$$

$$i.e.\ \sum_{l \in Tx(w_w)}(a_l) - \sum_{l \in Rx(w_w)}^{O}(a_l) = N_t\, \mathcal{S}_{w_w}$$

$$a_l - n_{t_l}\, log\left(1 - \frac{D_{g_{ll}}\mathcal{P}_l^{max}}{N_0}\right) \leq 0$$

$$\sum_{l \in Tx(w_w)} \zeta n_{t_l}\left(e^{\frac{a_\ell}{n_{tl}}} - 1 + \frac{P_{tcon}}{\zeta}\right) + \sum_{l \in Rx(w_w)} P_{rcon}\, n_{t_l} \leq O N_t \mathcal{E}_{w_w}$$

$$\sum_{l\in L} n_{t_l} \leq N_t,\ a_l, n_{t_l} \geq 0, n_{t_l} \in \{0, \cdots\cdots, N_t\}$$

Where l represents the link, the number of slots assigned on l is n_{t_l}. $Tx(w_w)$ is the set of transmitting links and $Rx(w_w)$ is the receiving links of the sensor node $w_w \in W$.The variable is ζ defined as follows

$$\zeta = \frac{N_0\,(1+\alpha)}{D_{g_{l\,l}}}$$

And a_l is defined as

$$a_l = m_{r_l} \times n_{t_l}$$

The transmission power the l^{th} link represented as $\mathcal{P}_l$ is defined as

$$\mathcal{P}_l = \frac{\mathrm{N}_0}{D_{g_{l\,l}}}\left(e^{\mathrm{m_r}\ell} - 1\right).$$

It must be noticed that the power of transmission over a network link l is presented as

$$\mathcal{P}_l = \frac{N_0}{D_{g_{ll}}}\left(e^{m_r\,l} - 1\right)$$

c) Cross Layer Optimization to Realize Elephant Swarm Behavior

The presented section of this paper elaborates the elephant swarm optimization algorithm for routing, $TDMA\ MAC$ scheduling and advanced radio layer control techniques. The elephant swam optimization is applied taking into account unconstrained scheduling on the network links. The elephant swarm optimization enables simultaneous $TDMA$ scheduling of the sensing data on the interfering wireless communication links in the current considered scheduling time slot. The elephant swarm optimization iterates to obtain an optimal routing, power consumption and $TDMA\ MAC$ schedule to enhance the considered network lifetime. The elephant model is adopted to solve optimization objective $min.(O)$ defined in the former section of this paper.

Let us consider a $TDMA$ link schedule of data defined as L^{n_t} where $n_t \in \{1,\cdots\cdots\cdots,N_t\}$. The rate of transmission that can be supported over a link $l \in L$ can be expresses as based on approximations is defined as

$$m_{r_l}^{\;n_t} \le \log\left(\frac{D_{g\,ll}\mathcal{P}_l^{n_t}}{\sum_{k\neq\ell,k\in L^{n_t}} D_{g\,l\,k}\mathcal{P}_k^{n_t} + \mathcal{N}_0}\right)$$

If the $SINR$ of a link $l \in L$ is γ then the minimum transmission rate is defined as follows

$$log(\gamma)$$

The elephant swarm optimization results arising based on the above approximations for $m_{r_l}^{\;n_t}$ are said to be a part of the $min.(O)$ function optimization set.

Let us define a variable

$$\mathcal{J}_l^{n_t} = \log\left(\mathcal{P}_l^{n_t}\right)$$

Then the above equation for the maximum transmission rate optimization $m_{r_l}^{\;n_t}$ can be defined as can be

$$log\left(\frac{N_0}{D_{g_{ll}}}\, e^{m_{r_l}^{\;n_t}} - \mathcal{J}_l^n + \sum_{\mathcal{K}\in L^n,\mathcal{K}\neq L} \frac{D_{g_{l\mathcal{k}}}}{D_{g_{ll}}}\, e^{m_{r_\ell}^{\;n_t}} + \mathcal{J}_{\mathcal{k}}^{n_t} - \mathcal{J}_\ell^{n_t}\right) \le 0$$

Based on the above arguments the elephant swarm optimization objective $min.(O)$ can be expressed as

$$\mathcal{A}(m_r^{\;1} + \cdots\cdots\cdots + m_r^{\;N_t}) = (\mathcal{S} \times N_t)$$

$$log\left(\frac{N_0}{D_{g_{ll}}}\, e^{m_{r_l}^{\;n_t}} - \mathcal{J}_l^n + \sum_{\mathcal{K}\in L^n,\mathcal{K}\neq L} \frac{D_{g_{l\mathcal{k}}}}{D_{g_{ll}}}\, e^{m_{r_\ell}^{\;n_t}} + \mathcal{J}_{\mathcal{k}}^{n_t} - \mathcal{J}_\ell^{n_t}\right) \le 0\,,\ \ \forall\, l \in L$$

$$\sum_{n_t=1}^{N_t}\left(\sum_{l\,\in\, Tx(w_w)\cap L^{n_t}} \left((1+\alpha)e^{\mathcal{J}_l^{n_t}} + P_{tcon}\right) + \sum_{l\,\in\, Rx(w_w)\cap L^{n_t}} (P_{rcon})\right) \le O N_t \mathcal{E}_{w_w}$$

The above defined elephant swarm optimization is applicable provided

$m_r^{\;n_t} \ge 0$

$\mathcal{J}_l^{n_t} \le \log(\mathcal{P}_l^{max})$

$l \in L^{n_t}$ and

$n_t = \{1,\cdots\cdots\cdots,N_t\}$

In other terms the elephant swarm optimization is applicable if the links have a $SINR$ greater than unity.

The $TDMA\ MAC$ scheduling over all the links is not adopted as the power consumption would exponentially increase. The elephant swarm optimization is applied on all the $TDMA$ links scheduled L^{n_t}. The computational complexity of optimization under such circumstances can be defined as

$$C_{Complex} = 2^{(L \times N_t)}$$

From the above equation it is evident that the $TDMA\ MAC$ optimization is computationally heavy and increases exponentially as the links of the sensor nodes increase (i.e. for dense networks) and the $TDMA$ slot value increases. The computation complexity of the elephant swarm optimization can be reduced if the number of $TDMA\ MAC$ slots are doubled to $2N_t$. The two fold increase in the number of time slots enables achieving lower power consumption as the sensor nodes have numerous slot options and sleep induction is effective. Furthermore in the case of high sensing activity leading to greater data transmissions, the data to the sink is scheduled using multiple TDMA slots to enable energy conservation and accurate data aggregation.

The elephant swarm optimization model can be summarized in the form of the algorithm given below realized through multiple phases described below.

Phase A

Initialize the schedule L^{n_t} based on the data $\mathcal{S}_{w_w}$. The L^{n_t} is initialized such that link $l \in L^{n_t} \forall l \exists n_t \in N_t. i.e.$ the schedule is constructed in a manner such that all the links $l \in L^{n_t}$ are provided at least a slot in N_t.

Phase B

In this phase the following equation is solved

$$\sum_{n_t=1}^{N_t}\left(\sum_{l \in Tx(w_w)\cap L^{n_t}}\left((1+\alpha)e^{\mathcal{J}_l^{n_t}} + P_{tcon}\right) + \sum_{l \in Rx(w_w)\cap L^{n_t}}(P_{rcon})\right)$$

If the results obtained on solving are not suitable $.i.e. > ON_t\mathcal{E}_{w_w}$ then the optimization is not possible. If the solutions satisfies the condition $\leq ON_t\mathcal{E}_{w_w}$ then elephant swarm route optimization and radio layer optimizations are carried out to support the required transmission rate.

Phase C

Evaluate all the links $l \in L^{n_t}$ and retain the links if the following equation is satisfied.

$$\frac{D_{g\,ll}\mathcal{P}_l^{n_t}}{\sum_{k\neq\ell,k\in L^{n_t}} D_{g\,lk}\mathcal{P}_k^{n_t} + \mathcal{N}_0} > \gamma_o$$

This phase eliminates all the links whose $SINR$ is less than unity and retaining the links having an acceptable $SINR$.

Phase D

Compute $\ddot{l}$ using the following equation

$$\ddot{l} = l_{Max}^{Crnt}\left(\sum_{n_t=1}^{N_t}(\mathcal{P}_l^{n_t})\right)$$

Compute $\ddot{n}_t$ defined as

$$\ddot{n}_t = n_{t\,Min}^{Crnt}\left(\sum_{k\neq\ddot{l},k\in L^{n_t}} D_{g\,\ddot{l}k}\mathcal{P}_k^{n_t} + \mathcal{N}_0\right)$$

Using the above definitions we can obtain the new the $TDMA\ MAC$ layer schedule represented as $L^{\ddot{n}_t}$ and $\ddot{l} \in L^{\ddot{n}_t}$. If the optimized $TDMA\ MAC\ L^{\ddot{n}_t}$ schedule is equitant to the existing or previous schedule then no further optimization is possible. If the optimized $L^{\ddot{n}_t}$ is not similar to the current and previous MAC layer schedule the new schedule is adopted. $L^{\ddot{n}_t}$ enables to identify the maximum power utilization link l so we can schedule it the additional slots available thus aiding energy conservation.

Phase E

In the last phase of the elephant swarm optimization algorithm the optimal solution achieved using a cross layer approach is verified using the following definition

$$\left(\frac{D_{g\,ll}\mathcal{P}_l^{n_t}}{\sum_{k\neq\ell,k\in L^{n_t}} D_{g\,lk}\mathcal{P}_k^{n_t} + \mathcal{N}_0}\right) \geq 1.0 \ \forall\, l \in L^{n_t}, n_t = \{1,\cdots\cdots\cdots,N_t\}$$

If the solution does not satisfy the above equation then no optimization is possible owing to current network dependent reasons. If optimal solution is obtained and incorporated network performance in terms of data aggregation, improved data rates and higher network lifetimes.

The elephant swarm optimization is realized using a cross layer design approach to enhance network lifetime. The efficiency and the performance measure of this optimization technique is discussed in the subsequent section of this paper.

IV. Experemential Study

In this section of the paper we shall discuss the experimental study conducted to compare the elephant swarm optimization algorithm introduced in this paper with the popular LEACH [15] protocol. The elephant swarm optimization model and the LEACH protocol was developed on the SENSORIA Wireless Sensor Network Simulator [18] [19] [20] [21]. The elephant swarm optimization algorithm was developed using the C# language on the Visual Studio 2010 platform. The simulations were executed on a $i7$ Quad Core CPU having 8GB of RAM to conduct the experimental study.

The wireless sensor network test bed was considered to be spread over a terrain measuring 25×25 meters. The wireless sensor nodes deployed over the terrain are varied from 450,500,550,600,650 and 700 nodes respectively. The test bed considered sensor nodes mounted with temperature sensors having a sensing range of 3m. The radio range considered is 5m. Sensing events are induced every 0.1 seconds. Inducing such high sensing activity and considering dense networks enables high traffic injection into the test bed. High traffic injection considered in the test beds results greater data transactions resulting in rapid energy depletion in the overall network. The simulation study was conducted to observe the network life time of the test bed. The threshold of the network lifetime analysis was set to 30% i.e. the simulation study was conducted until 30% of the network energy depletes.

To prove the efficiency of the elephant swarm optimization algorithm network test beds with varied nodes densities (i.e. 450,500,550,600,650 and 700) was simulated. The total network energy depletion was initiated by inducing sensing events. Similar network topology was considered to simulate the Elephant Swarm Optimization algorithm and the popular LEACH test bed. High traffic injection considered in the test beds results greater data transactions resulting in rapid energy depletion in the overall network. The simulation study was conducted to observe the network life time of the test bed. The threshold of the network lifetime analysis was set to 30% i.e. the simulation study was conducted until 30% of the network energy depletes.

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The rate at which the sensor node energy decays with time is also observed ad the results obtained is shown in Figure 2. The Elephant Swarm optimization model proposed in this paper adopts a cross layer approach when compared to the LEACH protocol. The optimization technique proposed enables the balanced data scheduling on the links L that exist and hence reduces the energy decay rate of the sensors nodes by about 81.9%.

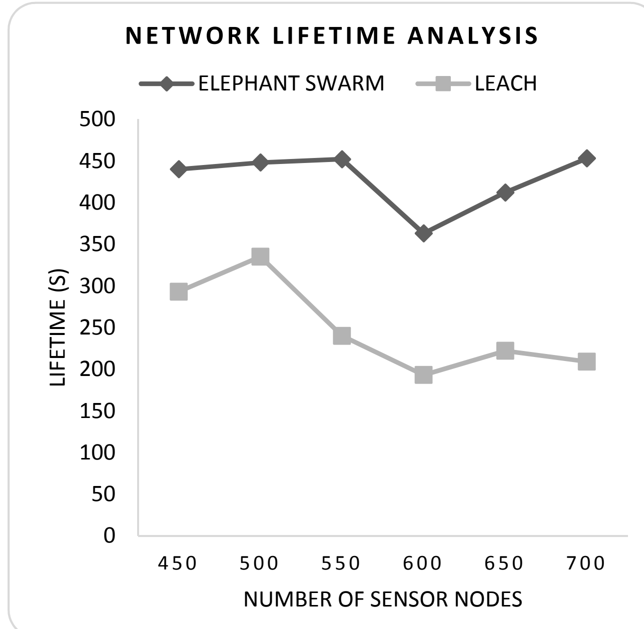

Figure 1 : Network Lifetime Analysis

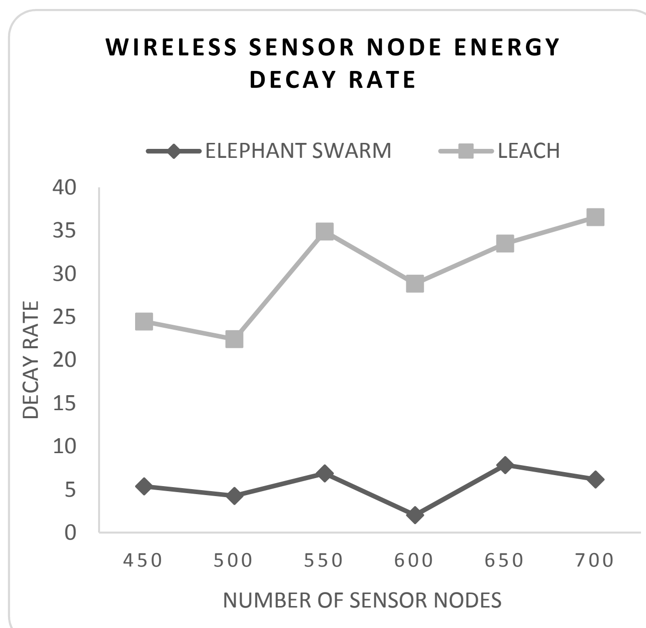

Figure 2 : Wireless Sensor Node Energy Decay Rate

The elephant swarm optimization proposed also enables communication overhead reduction even for dense wireless sensor networks. The communication overheads are reduced greatly by the reduction of the number of retransmissions of data packets and optimized routing incorporated in the elephant swarm model. The communication overhead of the LEACH protocol is about 36.6% greater than that of the proposed optimization model. The results obtained are as shown in Figure 3 of this paper.

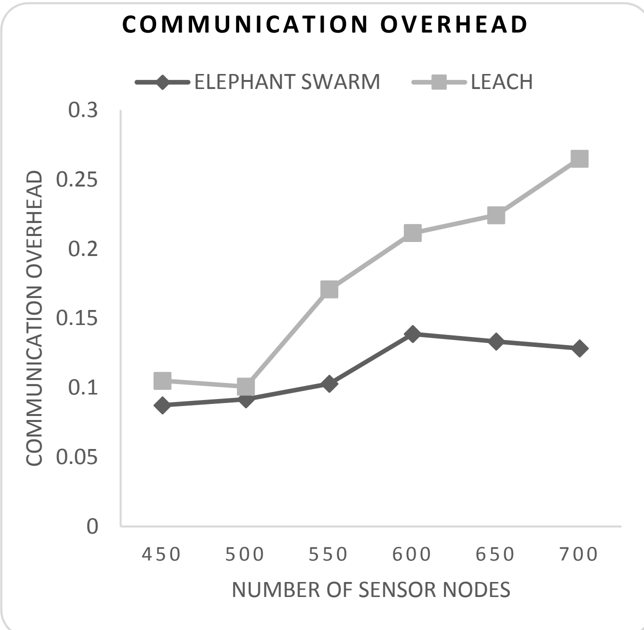

Figure 3 : Communication Overhead Analysis

To prove the increase in network lifetime the ratio of the sensor nodes active at regular time intervals is noted the results obtained are shown in Table 1. These results have been obtained for varying sensor node deployment densities. The graphical analysis is presented in Figure 4 of this paper given below. The results described in the table prove that the percentage of active nodes using the elephant swarm optimization is greater than the nodes alive while using the LEACH protocol.

Table 1 : Active Node Ratio with respect to the Simulation Instance and Network Topology Size

Number of Sensor Nodes	Sim Time (S)	Elephant Swarm Active Node Ratio	Leach Active Node Ratio
450	293	99.77777778	79.55555556
500	335	99.8	80.6
550	240	99.81818182	77.27272727
600	193	99.83333333	80.66666667
650	222	99.84615385	77.53846154
700	209	99.85714286	76.42857143

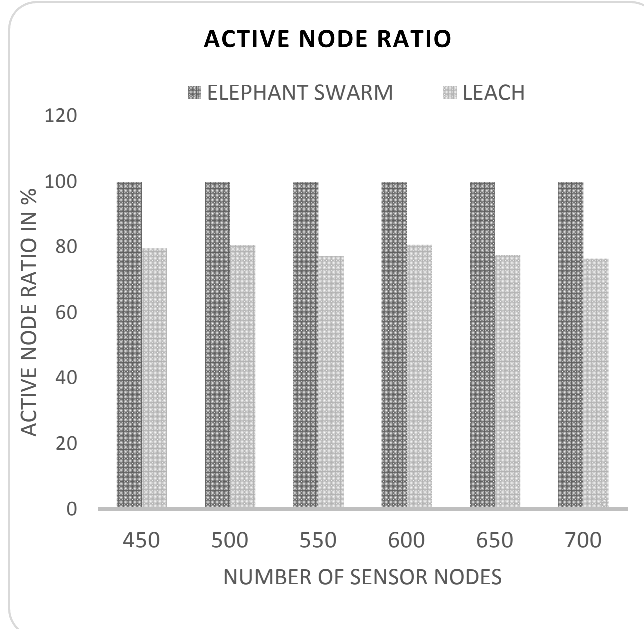

Figure 4 : Active Node Ratio in the Test Bed Observed at Constant Simulation Slots

The experimental study discussed in this section of this paper proves that the elephant swarm optimization technique proposed in this paper exhibits better network performance than the popular LEACH protocol commonly used. The enhanced networks performance is proved in terms of network lifetime, communication overhead reduction, reduced energy decay in the sensor nodes and enhanced active node ration in the network.

V. Conclusion and Future Work

In this manuscript the authors address the problem in enhancing the network lifetime of wireless sensor networks. The elephant swarm optimization technique is adopted to address the issue that exists. A cross layer approach is adopted to incorporate optimizations at the routing, radio and the MAC layers. A TDMA based MAC layer is considered and the MAC schedule is optimized in accordance to the routing and the radio link layer optimization. The system model considered is clearly discussed. The optimization function which needs to be solved using the elephant model is also discussed. The elephant swarm optimization is achieved using a phased approach discussed in this paper. The experimental evaluation conducted proves the efficiency of the proposed elephant swarm optimization technique over the popular LEACH protocol in terms of improved network lifetime, reduced sensor node energy decay rate, higher active node ratios and lower communication overheads. The overall network lifetime of the varied scenarios presented proves enhancement of about 73% thus justifying the robustness of the proposed elephant swarm optimization technique.

The future of this work can be considered to compare the elephant swarm optimization technique with other swarm optimization techniques like particle swarm, ant swarm and a few other evolutionary computing based optimization techniques and prove its robustness.

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