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Network Lifespan Maximization For Wireless Sensor Networks Using Nature-Inspired Elephant Based Swarm Optimization

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Abstract: *The robust and complex real-time applications and dramatically increased sensor capabilities may play a vital role in enhancing the lifespan of WSNs. On the other hand majority of WSNs operate on battery powered infrastructure, therefore in order to enhance the lifespan maximization a robust and highly efficient protocols are required to be developed that can effectively minimize the battery utilization and the overall computational as well as communication complexity also could be minimized. Optimizations required to be adopted at the Routing Layer, MAC Layer and the Radio Layer of the wireless sensor node. In this paper in order to achieve a better network performance an scheme of elephant swarm optimization has been implemented which enables optimization of routing algorithm, adaptive radio link optimization and balanced TDMA MAC scheduling. The proposed Elephant Based Swarm Optimization scheme is analyzed and compared with the popular LEACH and PSO Protocols and results proves that the EBSO algorithm is the best among PSO and LEACH schemes.*
Keywords: *Active node ratio, Cross-layer design, Elephant Based Swarm Optimization (EBSO), LEACH, Network lifespan, Particle Swarm Optimization (PSO).*

I. INTRODUCTION

Here we consider a topology of wireless sensor networks deployed across a predefined geographical areas. The sensor nodes are assumed to have homogenous energy parameters and they operated by battery with finite energy and which is the case most often than not. The sensor deployment across the geographical areas is considered to be dense to achieve higher transmission data rates. Because of dense deployments huge number of links are established induce interference across the sensor nodes which requires be minimized to achieve better network performance in terms of throughput. This paper introduces an Elephant Based Swarm Optimization (EBSO) model to enhance network lifespan. A cross-layer scheme is adopted to incorporate the elephant based swarm optimization characteristics and features.

Elephants are social mammals [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 cluster [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 or segregate from the cluster. Elephants by nature are stronger protective of their younger generation. Elephants communicate using varied advanced techniques such as acoustic communication, chemical communication, visual communication and tactile communication and characteristics and empowering their memory system described in [4][5][6]. 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 so complex, robust and to realize such behaviors in wireless sensor networks the authors have proposed to use a cross-layer scheme to incorporate the elephant based 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 scheme to incorporate the Elephant Based Swarm Optimization technique which is compared with the popular $LEACH$ protocol of conventional scheme and Particle Swarm Optimization (PSO) of Evolutionary schemes and its efficiency is proved in the latter section of this paper.

II. LITERATURE REVIEW

The literature review discussed in this paper prioritizes the cross layer architectures proposed by researchers to overcome the drawbacks that exist in wireless sensor networks through which performance will be maximizing. A research work [7] elaborates the fundamental concept of sensor networks which has been made viable by the convergence of micro electro-mechanical 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 network 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 scheme, 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 and analyzed with Genetic Algorithm concept 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] describes 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 schemes 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] suggests that the cross-layer architecture based an opportunistic MAC protocol that integrates and merges 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 scheme, 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 mechanism 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.

Consider 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 scheme the carrier-sensing technology is applied at the PHY 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 MAC facilitates the receiver of the ascending hop on the path of routing that has to be effectively wakened up and ultimately it results into the potential reduction in energy consumption.

Consider 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 stated in [15]. 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 technique incorporated by researchers to maximizing the network lifespan of wireless sensor networks is also considered during the course of the research presented here [16] [17] [22].

2.1 Special Cross-layer Issues with WSN

Comparing with the ISO/OSI-based model which is more connection oriented, with less constraints and for more general purpose usage, WSN is task oriented, with more constraints and for specific application. Therefore, research works on WSN in area of cross-layer design become more challenging due to its unique characteristics. One of the design goals is to prolong its lifespan [26][27]. Other important design goals are to provide stable network coverage and reliable data fusion or control estimation [28][29]. Most of the works have presented the benefits by joint design across NWK, MAC and PHY layers without considering QoS at application specific. For example, based on the single layer energy optimization strategy for MQAM and MFSK modulation [30], a joint optimization between MAC and data link layer was solved by convex relaxation methods [31]; under TDMA approach, transmission energy optimization should be considered for multi-hop [32] routing case while circuit processing energy optimization was considered for single-hop case [33].

The optimal results for the tradeoff should be driven by the consideration of application layer for cross-layer design for WSN and QoS requirement in application layer play a leading role for cross-layer optimization issues [34]. However it is a challenge to build general model to address the cross-layer issue with application layer for different application specifications. Some results from real-time tracking applications with cross-layer optimization have been reported: e.g. the algorithm based on the tradeoff between communication and sensing objectives to handle interference of physical and application layers [35]; the cross-layer strategy of sharing information between the PHY and application layers in the design Kalman filter for the real-time estimation [36].

Cross-layer scheme has also been tried out in the TinyOS, an open source embedded operating system for many sensor network platforms. An adaptive cross-layer framework called Tiny Cube provides a generic interface and a repository for the multi-layer information exchange and management [37]. Under the IEEE standard 802.15.4, The distributed algorithm explores the cross-layer between MAC and PHY layer to manage the activities of sensor nodes [38].

III. WIRELESS SENSOR NETWORK FOR ELEPHANT BASED SWARM OPTIMIZATION

3.1 System Modeling for WSN

The system modeling section represents the scheme and techniques being implemented so as 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

$W = \{w1, w2, w3,\dots ww\}$ ....(1)

Consider the network W, the wireless communication links that exist between two nodes $w1 \in W$ and $w2 \in W$, 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 ($SINR$) of a communication link is represented by γ then the maximum data rate supported (m_r) per unit bandwidth is defined as

$m_r = log\ (1+(B\times\gamma))$ ....(2)

Where $B = (-1\cdot5) / (log(5BER))$

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 Nt 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 P_t then the power consumption of the amplifier is defined as

$(1 + \alpha)P_t$

Where α is the efficiency of power amplifier and $\alpha>0$ to achieve the desired signal amplification. A homogenous sensor network model is considered $i.e. \forall\ w_w \in W: \alpha1=\alpha2=\dots=\alpha_w$.

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

$Dg = (\ W\ L\ )$ …………..(3)

Where L indicates set of directed links.

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

$$\mathcal{A}(w_w, \ell) = \begin{cases} -1 & If\ w_w \text{ is the receiver of link } \ell \\ 0 & in\ other\ cases \\ +1 & If\ w_w \text{ is the transmitter of link } \ell \end{cases} \quad \dots\dots\dots\dots\dots..(4)$$

We present an expression

$$\mathcal{A} = \mathcal{A}^+ - \mathcal{A}^- \quad \dots\dots\dots(5)$$

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

As discussed earlier 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

$n_t \in \{1, \cdots\cdots\cdots, N_t\}$ ………(6)

$P_l^{n_t}$ and $m_{r_l}^{n_t}$ represents the power of transmission and per unit bandwidth rate respectively over link *l* and n_t slot^{S}. 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 *l*. The analogous vector is $P^{max} \in \mathcal{R}^{|L|}$. The vectors $1_t(P^{n_t})$ id defined as

$$\left(1_t(P^{n_t})\right)_{w_w} = \begin{cases} 1 & if((e_v^{+})^T \times P^{n_t}) > 0 \\ 0 & In\ other\ cases \end{cases} \quad ………..(7)$$

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

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

$$\left(1_{m_r}(P^{n_t})\right)_{w_w} = \begin{cases} 1 & if((e_v^{-})^T \times P^{n_t}) > 0 \\ 0 & In\ other\ cases \end{cases} \quad …………(8)$$

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 $\boldsymbol{P_{tcon}}$ represents energy consumption of transmitter and $\boldsymbol{P_{rcon}}$ represents the energy consumption of the receiver and is assumed to be homogenous for all the nodes. The energy 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

$$\mathcal{S}_{Sink} = -\sum_{w_w \in W, w_w \neq Sink} \mathcal{S}_{w_w} \quad ………(9)$$

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

$$D_g = \mathcal{R}^{|L| \times |L|} \quad …………(10)$$

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.

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

$$\left(1 + (\mathcal{K} \times log(SINR))\right) \quad ……….(11)$$

3.2 Objective Concern on Elephant Based Swarm Optimization for WSN

A cross layer scheme is incorporated to enhance the network lifetime of the wireless sensor network. Elephants are social mammals and are said to possess strong memory of the events that occur. The problem of optimizing or maximizing the lifespan of the network will be presented as a function defined as follows

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

$$i.e. \frac{1}{N_t}\mathcal{A}(m_r^{1} + \cdots\cdots\cdots + m_r^{N_t}) = \mathcal{S} \quad …………(12)$$

$$log\left(1 + \mathcal{K}\frac{D_{g_{ll}}\mathcal{P}_l^n}{\sum_{\mathcal{K} \neq l} D_{g_{lk}}\mathcal{P}_k^n + \mathcal{N}_0}\right) \geq m_{r_l}^{n_t} \quad …………(13)$$

The maximization function $max.(\mathcal{T}_{net})$ is presented briefly in [25].

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

Let us define a variable O such that

$$O = (\mathcal{T}_{net})^{-1} \qquad \text{............(14)}$$

The elephant swarm optimization is applied to attain minimized function defined as $min.(O)$

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

$$log\left(1 + \frac{D_{g_{ll}} \mathcal{P}_l^{n_t}}{\sum_{\mathcal{K} \neq l} D_{g_{lk}} \mathcal{P}_k^{n_t} + \mathcal{N}_0}\right) \geq m_{r_l}{}^{n_t}) \qquad \text{..........(15)}$$

The minimization function or the elephant based swarm optimization objective $min.(O)$ and which is defined in [24] [25].

The model presented here considers TDMA based MAC systems the minimization function is defined as *min(O),* And which is been clearly explained in [24] [25], and finally it generates the transmission link for the communication.

$$\sum_{l \in L} n_{t_l} \leq N_t, a_l, n_{t_l} \geq 0, n_{t_l} \in \{0, \cdots\cdots, N_t\} \qquad \text{..............(16)}$$

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 ζ is defined as follows

$$\zeta = \frac{N_0(1 + \alpha)}{D_{g_{ll}}} \qquad \text{..............(17)}$$

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

$$\mathcal{P}_l = \frac{N_0}{D_{g_{ll}}}(e^{m_r l} - 1) \qquad \text{..........(18)}$$

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

$$\mathcal{P}_l = \frac{N_0}{D_{g_{ll}}}(e^{m_r l} - 1) \qquad \text{.............(19)}$$

3.3 Phased Schemes to Realization of Elephant Based Swarm Behavior for WSN

The presented section of this paper elaborates the Elephant Based Swarm Optimization (EBSO) algorithm for routing, TDMA MAC scheduling and advanced radio-layer control techniques. The elephant based swam optimization is applied taking into account unconstrained scheduling on the network links. The EBSO scheme 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 lifespan. The elephant based model is adopted to solve optimization objective *min.(O)* defined in the former section of this paper.

TDMA link schedule, minimum and maximum transmission rate optimization are presented and proves in [24][25] through mathematical calculations and models.

The defined elephant based swarm optimization [24][25] is applicable provided

$$m_r{}^{n_t} \geq 0$$

$$\mathcal{J}_l^{n_t} \leq \log(\mathcal{P}_l^{max}) \qquad \text{............(20)}$$

$l \in L^{n_t}$ and $n_t = \{1, \cdots\cdots\cdots, N_t\}$

In other words the elephant based 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 based 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

$$C_{Complex} = 2^{(L \times N_t)} \qquad \text{.........(21)}$$

From the above equation it is eproved that the TDMA MAC optimization is computationally more load and maximizes exponentially as the links of the sensor nodes increase (i.e. for dense networks) and also the TDMA slot value increases. The computation complexity of the elephant based 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.

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

Phase 1:

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 formed in a manner such that all the links $l \in L^{n_t}$ are provided at least a slot in $\boldsymbol{N_t}$.

Phase 2:

In this phase the following equation is solved

$$\sum_{n_t=1}^{N_t} \left(\begin{array}{c} \sum_{l \in Tx(w_w) \cap L^{n_t}} \left((1 + \alpha) e^{\mathcal{J}_l^{n_t}} + P_{tcon} \right) + \\ \sum_{l \in Rx(w_w) \cap L^{n_t}} (P_{rcon}) \end{array} \right) \qquad \text{............(22)}$$

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 satisfy 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 3:

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

$$\frac{D_{g_{ll}} \mathcal{P}_l^{n_t}}{\sum_{k \neq l, k \in L^{n_t}} D_{g_{lk}} \mathcal{P}_k^{n_t} + \mathcal{N}_0} > \gamma_o \qquad \text{.............(23)}$$

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

Phase 4:

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

$$\ddot{l} = l_{Max}^{Crnt} \left(\sum_{n_t=1}^{N_t} \left(\mathcal{P}_l^{n_t} \right) \right) \qquad \text{..........(24)}$$

Compute $\dddot{n}_t$ defined as

$$\dddot{n}_t = n_{t\,Min}^{\,Crnt} \left(\sum_{k \neq \ddot{l}, k \in L^{n_t}} D_{g_{\ddot{l}k}} \mathcal{P}_k^{n_t} + \mathcal{N}_0 \right) \qquad \text{...........(25)}$$

Phase 5:

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

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

$$= \{1, \cdots\cdots\cdots, N_t\} \qquad \ldots\ldots\ldots\ldots(26)$$

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.

IV. SIMULATION SETUP, RESULTS, AND COMPARISONS

This section discusses the experimental study conducted to compare the elephant based swarm optimization (EBSO) algorithm introduced in this paper with the popular optimization technique called Particle swarm optimization (PSO) and LEACH. The elephant based swarm optimization model, the PSO and LEACH protocols was developed on the SENSORIA Wireless Sensor Network Simulator [26][27] and which is developed using the C# language on the Visual Studio 2010 platform.

The experimental set up of wireless sensor network test bed was considered and which is given in the following table.

Table 4.1 Parameters and Values for WSN

Parameters Selection	Values
Number of Nodes	700
Size of the Region	25×25 Mtrs.
Network Environment	Temperature
Sensing Range	3 Meters
Radio propagation Range	5 Meters
Sensing event Time	0.1 Secs.

The incorporating wireless sensor nodes were deployed over the environment is varied from 450-to-700 (with 50 nodes varying) respectively. The induction of such high sensing commotion and deployment of dense networks enables high traffic injection into the test bed. The higher traffic injection that is considered in the test beds results into greater data transactions and ultimately resulting into swift energy depletion in the overall considered network and which is elaborated in [24][25].

These results have been obtained for varying sensor node deployment densities. The graphical analysis is presented in Figure 4.1, Figure 4.2, of this paper given below. The results described in the figures prove that the percentage of active nodes using the elephant based swarm optimization is greater than the nodes alive while using the LEACH and PSO optimization protocols.

The below presented graph (Fig:4.1) represent the active node ratio that states about the live nodes in the area of deployment. From this figure it is clear that at every size of group i.e.; at 450 to 700 nodes, at each circumstance the proposed elephant based swarm optimization has justified its robustness with presenting longer lifespan and of course higher active nodes. From the figure 4.1 it is proved that the conventional LEACH protocol and evolutionary PSO protocol having low active time as compared to elephant based swarm optimization based cross-layered wireless network.

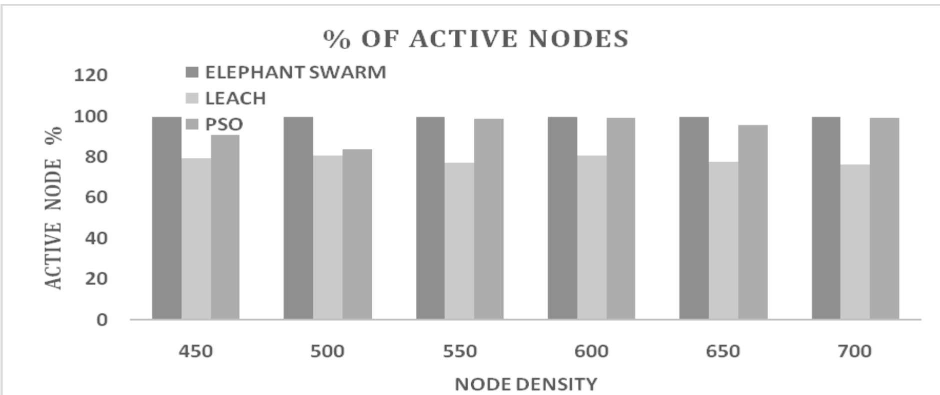

Figure 4.1: Comparison of Active Node Ratio With LEACH, PSO, and EBSO at Constant Simulation Slots

Figure 4.2 represents the overall life time analysis for different techniques and for the network of different size. In this graph the sensing nodes life time has been plotted with respect to the node density in the area of deployment or test bed. From the result Figure 4.2, it is clear that the lifespan of the nodes are much higher in the case of proposed cross-layer based elephant swarm optimization. Particle-swarm based model is having lower lifespan while LEACH is found to be more death prone. On the other hand from the above mentioned figure it can be easily found that the lifespan for nodes is increasing as the density is increased.

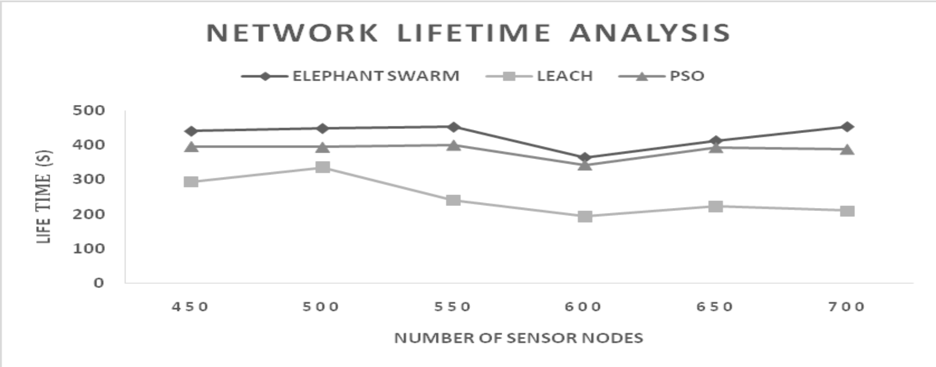

Figure 4.2 Wireless Sensor Network Lifetime Analysis

V. CONCLUSION

In this manuscript the authors address the problem in maximizing the network lifespan of wireless sensor networks. The elephant based swarm optimization technique is used to address the issue that exists. A cross-layer scheme is used 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 experimental evaluation conducted proves the efficiency of the proposed elephant based swarm optimization technique over the popular LEACH protocol and evolutionary PSO in terms of improved network lifespan, and higher active node ratios. The overall network lifespan of the varied scenarios presented proves enhancement of about 72.8% thus justifying the robustness of the proposed elephant based swarm optimization technique.

The future of this work can be considered to compare the elephant swarm optimization technique with other Swarm Intelligence based Swarm Optimization techniques like Genetic Algorithm (GA), Particle Swarm, Ant Swarm or Ant Colony Optimization and a few other evolutionary computing based optimization techniques and prove its robustness.

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