Virtual Cluster Head Based PSO and Fuzzy Logic Approach for WSN to Extend Network Lifetime

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***Abstract*— In recent times, Wireless Sensor Networks (WSNs) are broadly utilized in targeted monitoring applications. Traditional target coverage techniques usually consider that environment is known completely and every target is covered by single sensor. However those algorithms are inflexible when the sensor is about to die, that is, lack of energy and therefore target has to be covered with more than a sensor which is termed as n coverage crisis. In general, n coverage problem is energy and time consuming process, as well sensor organization is needed all the time. To resolve this crisis, this work anticipates a n coverage model with VCH-PSO (Virtual Cluster Head based Particle Swarm Optimization and EFLM (Energy management based Fuzzy logic Model) to enlarge the lifetime of WSN. During the search of optimal area coverage, diverse factors like node position, energy consumption, and coverage range of sensors are considered significantly. Simulation was carried out in MATLAB environment and compared with prevailing techniques. The proposed model shows better trade off in terms of network lifetime and time needed for switching between various coverage regions.**

Keywords— n-Coverage, WSN Lifetime, Target Monitoring, PSO, Fuzzy logic

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have been extensively utilized for tracking and monitoring applications like health care, industry and environmental monitoring. Every sensor has fixed location and sensors are organized into clusters termed sensor coverage to sense set of target distributed around a specific region for fixed amount of time [1]. This conventional target coverage methods considers that environment is well known and these algorithms tries to identify optimal sensor coverage that assist in extending the lifetime of network by covering every target by a single sensor. Moreover, those algorithms are specifically inflexible while sensor pretends to die, that is, sensor dies due to energy loss [2]. Therefore target has to be covered by more amount of sensor. Covering a target region with more than a single sensor node, leads to constant coverage. Moreover, it is energy and time consuming processes, organization of sensor nodes are essential all the time [3]. Therefore, n-coverage is generally a NP hard optimization problem that can be resolved using meta-heuristic optimization algorithm [4]. The above mentioned approaches finds a fixed directional sensor schedule which enhances the network lifetime.

Based on literature, Particle Swarm Optimization (PSO) is extensively utilized for optimization algorithm and it is used constantly in diverse applications specifically in WSN [5]. Genetic algorithm and Simulated Annealing were merged and a novel approach was illustrated for utilization of energy efficient coverage in WSNs.

Moreover, all the above stated algorithms consider that sensor coverage is generally static and it cannot be altered during network lifetime. Consider that prevention of PSO for sensor reconstruction of coverage region after every round gradually affects network lifetime [6]. In this crisis, data transmission for every round can be measured based on time period.

In this investigation, a novel Virtual Cluster Head based PSO model is utilized along with Energy management with Fuzzy Logic Model to attain an optimal sensor coverage that enhances network lifetime, and then it decides which sensor coverage has to be more active than others for present data transmission model [7]. Subsequently, PSO is used to monitor virtual cluster head and to optimize the performance of cluster head for meeting offer constant region for prolong time with restricted energy resources. By considering these set of factors like every sensors' coverage region, expected energy consumption, distance to base stations and target locations. VCH-PSO forms coverage region after describing the optimal virtual cluster head which is responsible for data transmission to base station. The following are the essential contributions of this work:

1) Virtual cluster Head based PSO model is created for all possible coverage known as n-coverage region.
2) Subsequently, coverage management technique switches from diverse coverage to enhance network lifetime.

Section II explains the proposed model for target coverage problem. Section III summarizes experimental results and discussions. Section IV presents conclusions and future work.

II. PROPOSED METHODOLOGY

a. System Model

The anticipated Virtual Cluster model follows the baseline principle of LEACH. Clusters are constructed in every round. In each clustering round, every node produces random number amongst 0 and 1. If random number for specific node is greater than Threshold value 'T', node starts to functions like cluster head as in fig 1. In case of conventional LEACH, cluster formation algorithm was distinct to guarantee that number of clusters formed per round is 'n' which is a system parameter [8]. Optimal value of 'n' in conventional LEACH can be described as communication energy and computation analytically. For example, if there 'N' nodes distributed randomly over M*M region, and 'n' clusters are considered, then there are N/n nodes for every cluster (one cluster head which is a virtual cluster head and (N/n)-1 for non-cluster head nodes. Every cluster head consumes energy by receiving signal, and aggregates the signal and transfers average signal to base station.

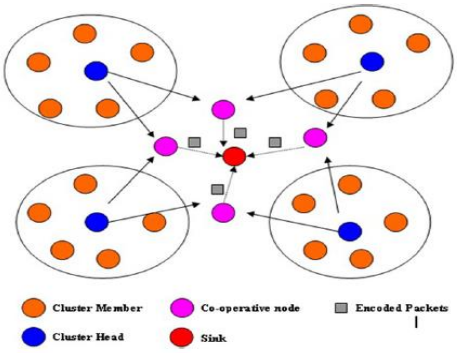


Fig. 1. WSN architecture

It is considered that sensor nodes transmit data after recognizing an interesting topic. The cluster head formed collects data and aggregates those collected data and transmits it to base station. To save certain energy, this wok considers a virtually formed cluster head amongst that CH and selects it to transmit data to BS, so as to utilize efficiently.

In this study, a virtual cluster head is constructed logically over sink node based on total amount of available residual energy of all successive CH. If a cluster head fails due to loss of energy, it can be managed by virtual CH. VCH are generated successfully by three successive cluster head. In case of failure in cluster members, virtual CH needs to transmit data of sensor nodes by successive CH (sense data by successive member). Virtual frame is utilized to specify sensed data of consecutive CH and failed member in VCH. Virtual frame is generated by sensing data of failed and consecutive members.

Note that, generally VCH does not exists really, which is constructed logically with consecutive CHs. Here, tolerance of VCH is evaluated using a heuristic model termed Particle Swarm Optimization along with the computation of transmission ability. It explains about re-direction of sensed data from VCH over successive CHs.

b. VCH based k-coverage PSO

In PSO approach, population of random candidate solutions are initialized for sensor network model, it is syntactically specified as particles termed swarm. Each particle is assigned with random velocity and it facilitates to traverse over problem space, i.e. failed node. Moving particles are captured towards best fitness location attained and best fitness location attained by entire population as in fig 2. PSO is easier to execute and every particle posses effectual memory capability.

Swarm particles determine sensors' position in region of interest (coverage) which is considered as 2D square area as in fig 3 & fig 4. Therefore, size of particles is twice as that of total amount of sensors. Final best particle specifies optimum location of sensors that causes minimum coverage holes (sensor region)

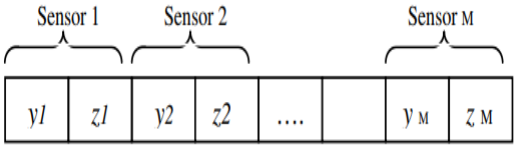


Fig. 2. : PSO position

c. Fitness Function

Maximum sensor coverage region is performed through area minimization of coverage holes. Coverage hole is a region which is not covered with the sensors' sensing field.

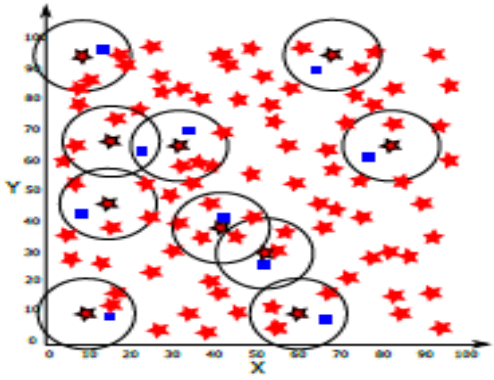


Fig. 3. Node coverage

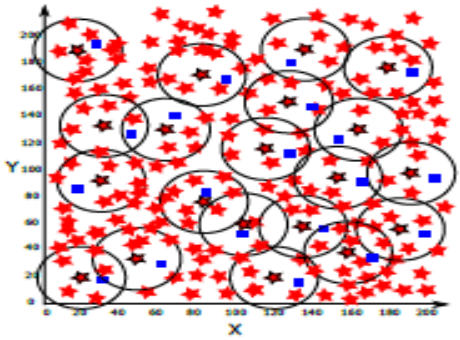


Fig. 4. N-node coverage

Generally, coverage hole area around region of interest is approximated based on location of interest point, it may be a boundary pout or vertex. Fitness is the summation of area with coverage holes in region of interest. Specifically, fitness value has to be Zero, specifying the occurrence of no coverage holes.

Based on the coverage region, movement of sensed data leads to energy consumption, which is extended to minimum fitness function as follows in Eq.1:

minimize $\sum_{\text{point} \in \text{region of interest}}$ coverage region (1)

$S_{mov} \leq S_{max}$ (2)

where S_mov is maximum distance movement of data from sensors and S_max is maximum distance of sensor as in Eq. [2] which is rewritten based on Penalty:

minimize $\sum_{\text{point} \in \text{region of interest}}$ coverage region + γ $P(S_{mov})$ (3)

Absolute penalty is provided as below in Eq. 4:

$P\ (S_{mov}) = \max(0, (S_{mov} - S_\max))$ (4)

$P\ (S_{mov})$ is zero as he constraint is fulfilled, however constraint is avoided when $P\ (S_{mov})\ is\ equal\ to$ p positive value. Optimal solution approximation for accuracy is determined with penalty model and managed with γ. Large value of γ results in higher penalty to certain constraints and makes it complex for optimal solution computation.

In this section Fuzzy logic model is modelled for Energy management in WSNs. It comprises of four elements, they are: Fuzzifier, Fuzzy interference engine, fuzzy rules and defuzzifier. Most extensively utilized fuzzy method is Mamdani method, which is considered for this investigation. Second fuzzy input variable is mobility of base station as anticipated model comprises of base station as mobile. Linguistic variables in association with mobility are low, moderate and frequent.

d. Fuzzification

Fuzzy system and interference approaches used for the anticipated model is given below in Table I. Here, three fuzzy input variables are considered for electing virtual cluster head.

TABLE I: FUZZY MEMBERSHIP TABLE

Membership functions		
Sensor battery power	**Centralized**	**Mobility**
Low (0)	Low (0)	Near (0)
Medium (1)	Moderate (1)	Adequate (1)
High (2)	Frequent (2)	Far (2)

e. Fuzzy rules and Interference engine

Based on the energy constraint of this system, diverse rules can be constructed. Rules are constructed with the following factors A, B, C and D. 'A' specifies remaining battery power of sensors, 'B' specifies mobility, 'C' specifies centrality and 'D' specifies chance.

$D = (A - 1) + B + c$ (5)

That is,

Chance=(Battery power-1) + mobility + centrality (6)

With respect to above equation, consider the remaining battery power as (Battery power -1) as in every round there is energy consumption at every node.

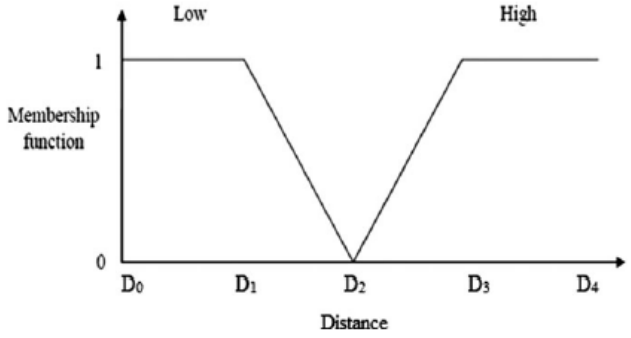


Fig. 5. Membership function

The energy management output is given as membership functions like, weak, very weak, medium, lower medium, higher medium, strong and very strong as in Fig 5.

III. EXPERIMENTAL RESULTS AND DISCUSSION

In this section, a series of experimentation is carried out to examine performance of anticipated model with three diverse n-coverage cases. As well, amount of energy consumed at every sensor node during specific transmission round was computed. Table II depicts the parameter settings that were utilized in this investigation. While executing VCH using PSO and Energy management with Fuzzy logic probability computation is carried out correspondingly.

TABLE II: PARAMETER SETUP

Parameters	**Values**
Number of nodes	100
Initial node energy	0.6J
Idle state energy	50nJ/round
Aggregation energy	5nJ/bit
CH to BS	10pJ/bit/m^2
Node to CH	0.0013pJ/bit/m^2
Packet size	500 bits

Here, time duration between initiations of network till initial target computation becomes uncovered that was utilized as network lifetime. Every experiment was iterated 10 times; average performance for 10 iterations was computed. However, in this investigation, dimension of first and second environment were 100 * 100 and 200 * 200 correspondingly.

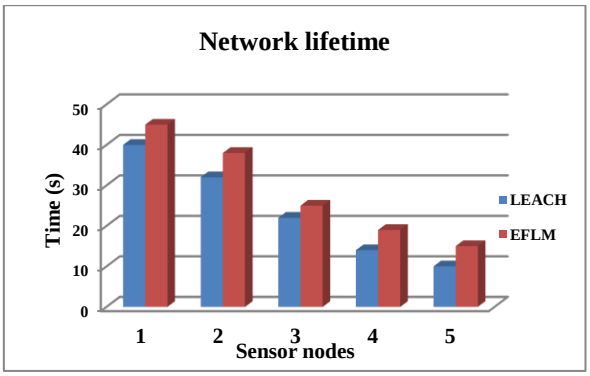


Fig. 6. Network lifetime

In initial iteration, three sub experiments were carried out to examine anticipated model with three diverse n-coverage cases as in Fig 6 (value of n is one, two and three). Here, round time for first target turns to be uncovered and round time of last target is also uncovered.

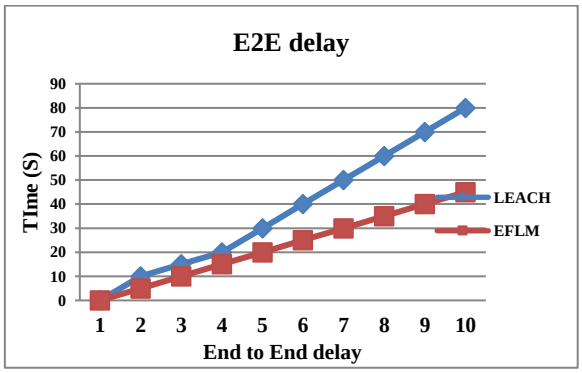


Fig. 7. E2E delay

Value of 'n' in sensing field increases and leads to more energy consumption for transmitting collected data; and therefore, network lifetime reduces [14-19]. Subsequently, network lifetime is inversely proportional to 'n' value. However, to enhance the performance of anticipated model with diverse values of 'n'. Moreover, enhancement of proposed model is attained with a range of 25% to 42%. Key enhancement of anticipated model is balanced between all sensors based on remaining energy with same energy level. In this study, average amount of target covered throughout the complete network lifespan is given as n=1, n=2 and n=3 correspondingly.

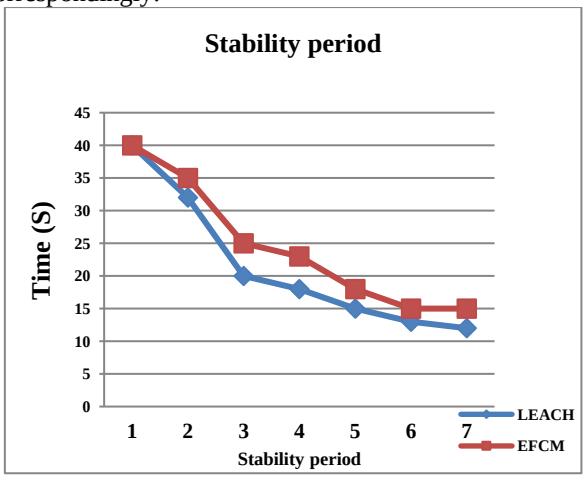


Fig. 8. E2E delay

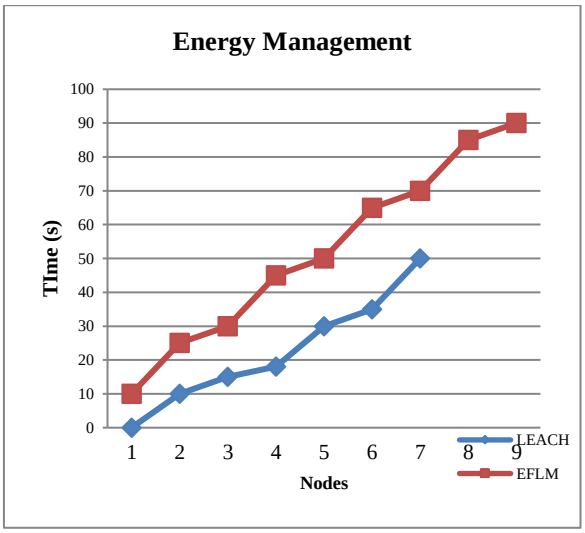


Fig. 9. Energy management

Fig 8 and fig 9 shows the stability period of nodes even in huge coverage region. Based on the proposed model, lifetimes of the nodes are increased and Energy management is effectual.

IV. CONCLUSION

Wireless sensor networks are utilized in diverse monitoring and tracking applications. In those applications, target covered by more than one sensor achieves continuous coverage. This work anticipates a novel n-coverage model based on Particle swarm optimization for VCH formation and EFLM (Energy management based Fuzzy logic Model) to extends the network life time. Amount of energy consumed is measured based on the active cover of next round. In contrast to prevailing works, the anticipated model shows enhanced performance relating to the amount of energy consumed, network lifetime and time needed to switch from diverse covers. However, this approach offers a framework that can be utilized both in static and dynamic mobile environments which is utilized for extending network lifetime in n-coverage model. As well, performance of this model requires the reality to be tested as a future direction.

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