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Performance Evaluation of PSO based optimization of Distributed Energy-Efficient Clustering (DDEEC) algorithm in heterogeneous WSN

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Abstract: Clustering in wireless sensor networks (WSNs) is used to expand the lifetime of the whole network through data aggregation at the cluster head. This paper investigates the performance of Particle Swarm Optimization (PSO) based DDEEC clustering protocol. This paper also presents the comparison of this PSO based protocol with the simple DDEEC protocol. PSO based DDEEC is based on the methodology of selecting a CH which is needed along with a strategy to rotate this responsibility among the sensor nodes. Matlab is used as Simulation tool to implement this algorithm. Simulation results demonstrate that the proposed protocol using PSO algorithm has higher efficiency and can achieve better network lifetime and data delivery at the base station over its comparatives.

Keywords: Clustering, DEEC, DDEEC, Energy Efficiency, Intelligent agents, Particle swarm optimization, Wireless sensor networks.

Introduction

PSO applies the concept of social interaction to problem solving. Particle Swarm Optimization (PSO) is a technique used to explore the search space of a given problem to find the settings or parameters required to maximize or minimize a particular objective. It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer). It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in a N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. The PSO algorithm works by simultaneously maintaining several candidate solutions in the search space. During each iteration of the algorithm, each candidate solution is evaluated by the objective function being optimized, determining the fitness of that solution. Each candidate solution can be thought of as a particle "flying" through the fitness landscape finding the maximum or minimum of the objective function. Initially, the PSO algorithm chooses candidate solutions randomly within the search space. It should be noted that the PSO algorithm has no knowledge of the underlying objective function, and thus has no way of knowing if any of the candidate solutions are near to or far away from a local or global maximum or minimum.

Katiyar et al. [21] surveyed clustering algorithms for heterogeneous wireless sensor networks. They classified clustering algorithms based on two main criterions: according to the stability and energy efficiency. They also surveyed several energy-efficient clustering protocols for heterogeneous wireless sensor networks. Dilip and Patel [22] proposed an energy efficient heterogeneous clustered scheme (EEHC), for electing cluster heads in a distributed fashion in hierarchical wireless sensor networks. The election probabilities of cluster heads are weighted by the residual energy of a node relative to that of other nodes in the network. The algorithm is based on LEACH and works on the election processes of the cluster head in presence of heterogeneity of nodes.

LITERATURE REVIEW

Clustering technique successfully organize the entire WSN into groups of clusters that are prepared to communicate within their clusters, but also able to aggregate information and report to the base station. Dilip and Patel [22] proposed an energy efficient heterogeneous clustered scheme (EEHC), for electing cluster heads in a distributed fashion in hierarchical wireless sensor networks. The election probabilities of cluster heads are weighted by the residual energy of a node relative to that of other nodes in the network. The algorithm is based on LEACH and works on the election processes of the cluster head in presence of heterogeneity of nodes. Simulations results show that EEHC is more effective in prolonging the network lifetime compared with LEACH.

Changmin Duan and Hong Fan [29] proposed a distributed energy balance clustering (DEBC) protocol for heterogeneous wireless sensor networks. Cluster heads are selected by a probability depending on the ratio between remaining energy of node and the average energy of network. The high initial and remaining energy nodes have more chances to be the cluster heads than the low energy nodes. This protocol also considers two-level heterogeneity and then it extends the results for multi-level heterogeneity. DEBC is different from LEACH, which make sure each node can be cluster head in each $ni = 1/p$ rounds. Simulation results show that the performance of DEBC is better than LEACH and SEP.

Qing et al [30] proposed a distributed energy efficient clustering scheme for heterogeneous wireless sensor networks, which is called DEEC. In DEEC, the cluster heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster heads for nodes are different according to their initial and residual energy .The authors have assumed that all the nodes of the sensor network are equipped with different amount of energy, which is a source of heterogeneity. DEEC is also based on LEACH; it rotates the cluster head role among all nodes to expend energy uniformity. Two levels of heterogeneous nodes are considered in the algorithm and after that a general solution for multi-level heterogeneity is obtained. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is used to compute the reference energy that each node should expend during a round. Simulation results show that DEEC achieves longer lifetime and more effective messages than LEACH, SEP and LEACH-E.

DEVELOPED DISTRIBUTED ENERGY - EFFICIENT CLUSTERING PROTOCOL

A Elbhiri et al. [14] proposed a developed distributed energy efficient clustering scheme for heterogeneous wireless sensor networks. This technique is based on changing dynamically and with more efficiency the cluster head election probability. DDEEC is based on DEEC scheme, where all nodes use the initial and residual energy level to define the cluster heads. To evade that each node needs to have the global knowledge of the networks, DDEEC like DEEC estimate the ideal value of network lifetime, which is used to compute the reference energy that each node should expend during each round. In the scheme, the network is organized into a clustering hierarchy, and the cluster heads collect measurements information from cluster nodes and transmit the aggregated data to the base station directly. Moreover, the authors have supposed that the network topology is fixed and no-varying on time. The difference between DDEEC and DEEC is localized in the expression which defines the probability to be a cluster head for normal and advanced nodes. Simulation results show that the protocol performs better than the SEP and DEEC in terms of network lifetime and first node dies.

DDEEC uses same method for estimation of average energy in the network and CH selection algorithm based on residual energy as implemented in DEEC. Difference between DDEEC and DEEC is centered in expression that defines probability for normal and advanced nodes to be a CH. We find that nodes with more residual energy at round r are more probable to become CH, so, in this way node having higher energy values or advanced nodes will become CH more often as compared to the nodes with lower energy or normal nodes. A point comes in a network where advanced nodes having same residual energy like normal nodes. Although, after this point DEEC continues to punish the advanced nodes so this is not optimal way for energy distribution because by doing so, advanced nodes are continuously a CH and they die more quickly than normal nodes.

To avoid this unbalanced case, DDEEC makes some changes in DEEC to save advanced nodes from being punished over and again. DDEEC introduces threshold residual energy to save advanced nodes from being punished over and again as given below:

$$TH_{REV} = E_0 \left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}\right)$$

When energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both type of nodes use same probability to become cluster head. Therefore, CH selection is balanced and more efficient.

$$TH_{REV} \simeq (7/10)E_0$$

Average probability pi for CH selection used in DDEEC is as follows:

$$p_i = \begin{cases} \dfrac{p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} & for\ Nml\ nodes, E_i(r) > TH_{REV} \\ \dfrac{p_{opt}\, E_i(r)(1+a)}{(1+am)\bar{E}(r)} & for\ adv\ node, E_i(r) > TH_{REV} \\ C\,\dfrac{p_{opt}\, E_i(r)(1+a)}{(1+am)^{\sim}\bar{E}(r)} & for\ adv\ node, ml\ nodes\ E_i(r) \le TH_{REV} \end{cases}$$

Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a technique used to explore the search space of a given problem to find the settings or parameters required to maximize or minimize a particular objective. This technique, first described by James Kennedy and Russell C. Eberhart in 1995, originates from two separate concepts: the idea of swarm intelligence based off the observation of swarming habits by certain kinds of animals; and the field of evolutionary computation. The PSO algorithm works by simultaneously maintaining several candidate solutions in the search space. During each iteration of the algorithm, each candidate solution is evaluated by the objective function being optimized, determining the fitness of that solution. Each candidate solution can be thought of as a particle "flying" through the fitness landscape finding the maximum or minimum of the objective function. Initially, the PSO algorithm chooses candidate solutions randomly within the search space. It should be noted that the PSO algorithm has no knowledge of the underlying objective function, and thus has no way of knowing if any of the candidate solutions are near to or far away from a local or global maximum or minimum.

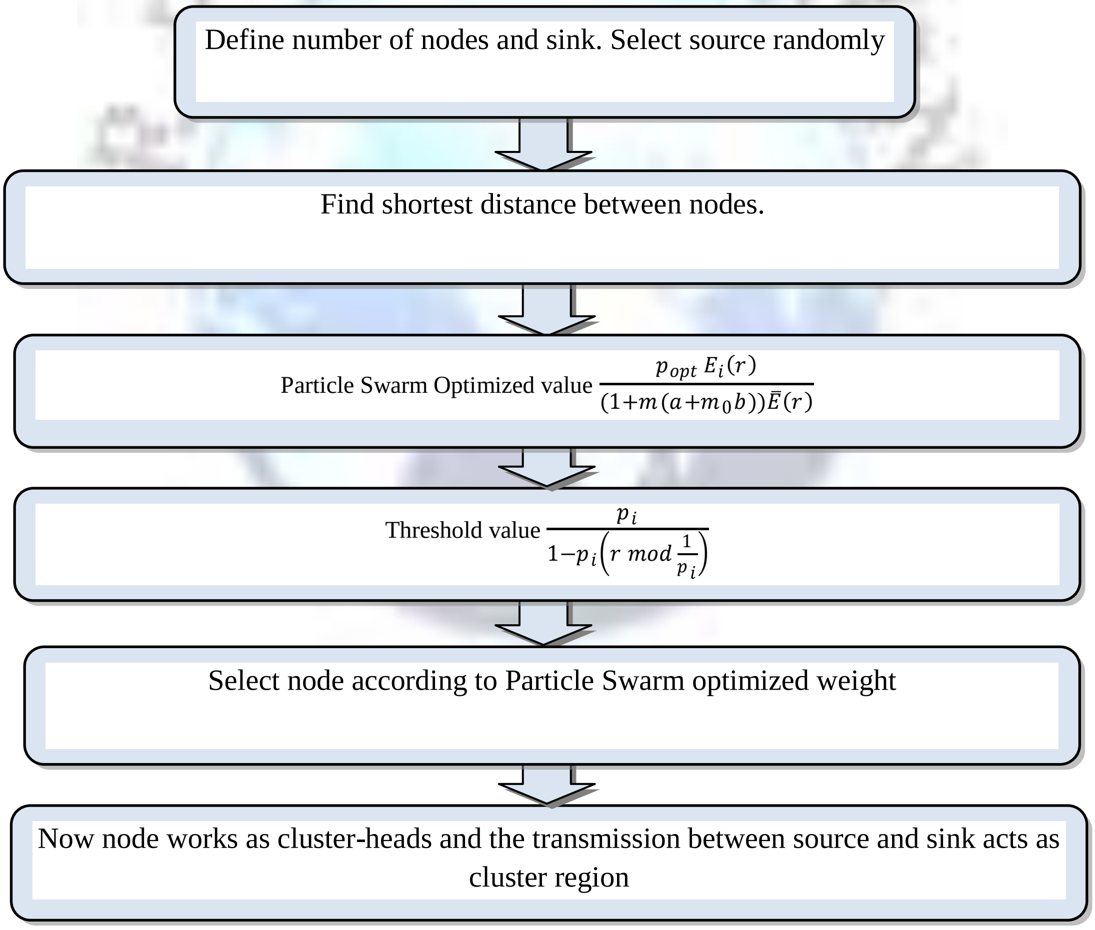

Fig 1: Flow diagram of Particle Swarm Optimized Cluster-heads

The original PSO algorithm was inspired by the social behavior of biological organisms, specifically the ability of groups of some species of animals to work as a whole in locating desirable positions in a given area, e.g. birds flocking to a food source. This seeking behavior was associated with that of an optimization search for solutions. The most common implementations of PSO, particles move through the search space using a combination of an attraction to the best solution that they individually have found, and an attraction to the best solution that any particle in their neighborhood has found. In PSO, a neighborhood is defined for each individual particle as the subset of particles which it is able to communicate with. The first PSO model used a Euclidian neighborhood for particle communication, measuring the actual distance between particles to determine which were close enough to be in communication. This was done in imitation of the behavior of bird flocks, similar to biological models where individual birds are only able to communicate with other individuals in the immediate vicinity. The Euclidian neighborhood model was abandoned in favour of less computationally intensive models when research focus was shifted from biological modeling to mathematical optimization. Topological neighborhoods unrelated to the locality of the particle came into use, including what has come to be recognized as a global neighborhood, gbest model, where each particle is associated with and able to obtain information from every other particle in the swarm.

Particle Swarm Algorithm

1. Begin
2. Factor settings and swarm initialization
3. Evaluation
4. g = 1
5. While (the stopping criterion is not met) do
6. for each particle
7. Update velocity
8. revise place and localized best place
9. Evaluation
10. End For
11. Update leader (global best particle)
12. g + +
13. End While
14. End

The PSO procedure has various phases consist of Initialization, Evaluation, Update Velocity and Update Position

- **Initialization**

The initialization phase is used to determine the position of the m particles. The random initialization is one of the most popular methods for this job. There is no assurance that a randomly created particle be a better answer and this will make the initialization more attractive.

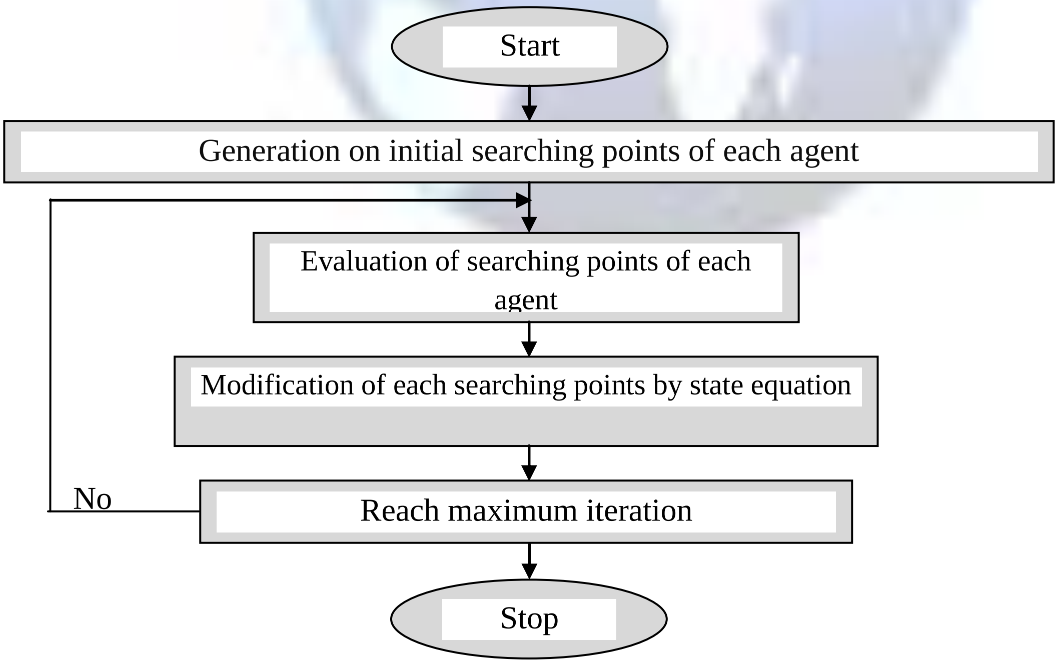

Fig 2: Flow chart of PSO

A good initialization algorithm makes the optimization algorithm more efficient and reliable. For initialization, initial information or knowledge of the problem can help the algorithm to converge in less iteration.

- **Update velocity and position**

In each iteration, each particle updates its velocity and position according to its heretofore best position, its current velocity and some information of its neighbor.

$$v_1(t) = \underset{inertia}{w\overline{v_l(t-1)}} + \underset{Personalinfluence}{c_1r_1\left(x_1^{\#}(t-1) - \overline{x_l(t-1)}\right)} + \underset{Socialinfluence}{c_2r_2\left(x^{*}(t-1) - \overline{x_l(t-1)}\right)}$$

Where,

$\overline{x_l(t)}$ = The position-vector in iteration t
i = The index of the particle
$\overline{v_l(t)}$ = The velocity- vector in iteration t
$x_1^{\#}(t)$ = The position so for of particle i in iteration t and its jth dimensional value is $x_{ij}^{\#}(t)$.
The best position vector among the swarm here to force is then stored in a vector $x^{*}(t)$ and its jth dimensional value is $x_{ij}^{*}(t)$.
r_1, r_2 = random numbers in the interval [0, 1].
c_1, c_2 = positive constants and
$w$is called the inertia factor.

This process is repeated until some stopping condition is met. Some common stopping conditions include: a pre-set number of iterations of the PSO algorithm, a number of iterations since the last update of the global best candidate solution ,or a predefined target fitness value.

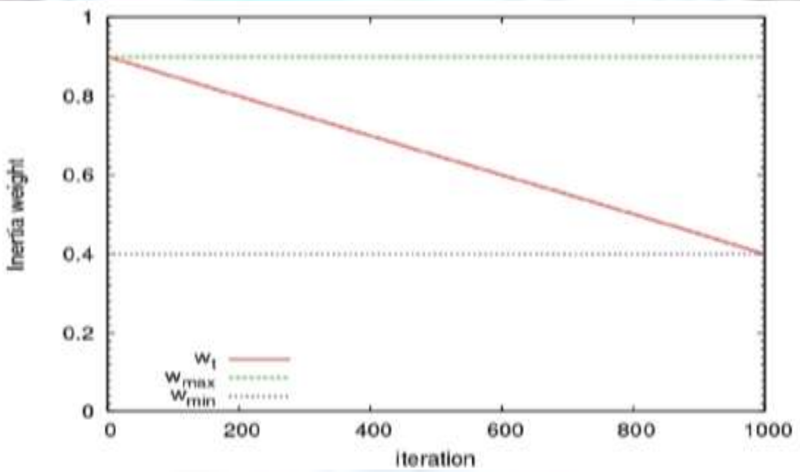

Fig 3: Iinertia weight value is decreased during a run

1.1 AODV Algorithm

1. // Initialization
2. // Setup network devices
3. // Build and update route
4. //Collect & store route stability
5. // Predict route stability Over Time
6. if stability meet
7. {
8. Switch route discovery and association
9. Send message
10. Build & update route
11. Collect & store route stability
12. Predict route stability Over Time

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13. if stability meet
14. {
15. Switch route discovery & Association
16. Send Message
17. Transfer control to line 1
18. else
19. Transfer control to line 10
20. }
21. else
22. Transfer control to line 1
23. }

Proposed Work

In a wireless sensor network with overlap and non-overlap communication various routing protocols have been proposed, where communication nodes plays an important role for energy efficient routing scenario. This paper proposes an efficient node selection scheme using particle swarm optimization technique for clustering in routing protocols. Nodes overheads are minimized by some cluster-heads and that cluster-heads are responsible for node selections and intercommunication within various nodes. This paper also proposes Particle Swarm optimized cluster-heads selection for End-to-End communication in routing protocol. The sink and source communicate with each other and maintain the routing with enough residual energy so that clustered structure may claim for maximum lifetime in a particular routing protocol.

Network Scenario

The paper proposes a network scenario where network nodes are dead initially unless and until it is triggered. Number of nodes has to be defining in a given network. Selection of nodes is random where source and sink are defined.

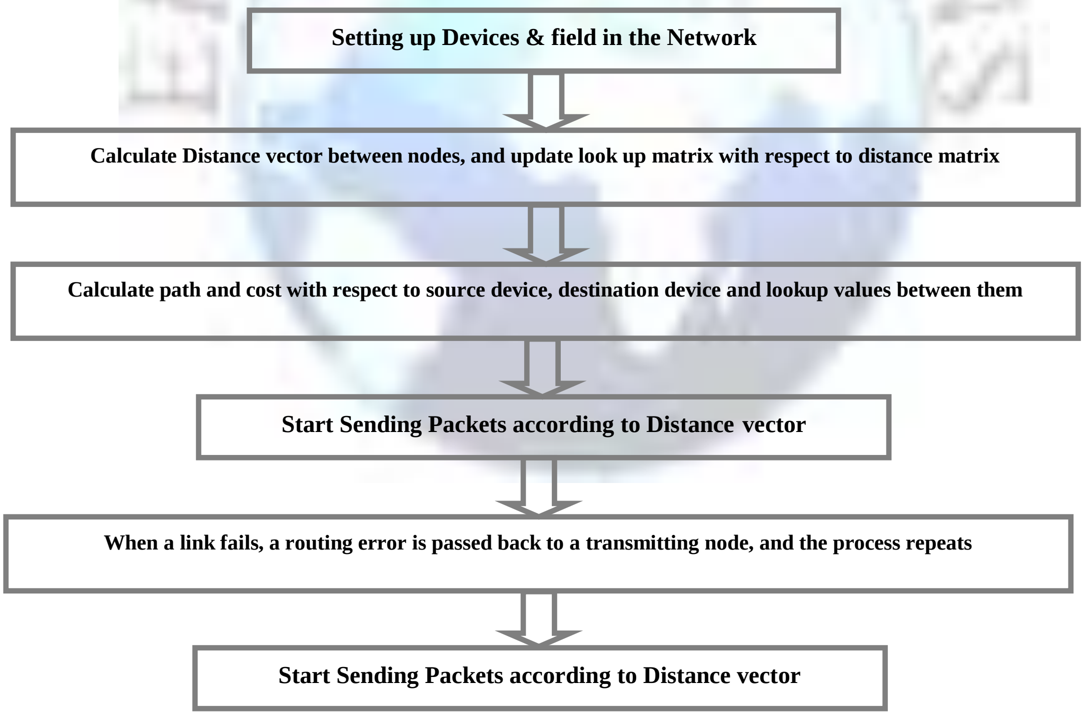

Fig 4: Flow chart of the PSO based DDEEC algorithm

Every node is initialized with common energy value (i.e. 1 Joule), later on the energy level of nodes may vary according to communication. Fig 4 shows the flowchart of the proposed work. Initially this algorithm calculates the shortest distance from sink for selection of source and then creates the cluster-heads or best selection of devices into the cluster which will be responsible for communication. Finally it will optimize the selection of cluster-heads using fitness function of Particle Swarm Optimization algorithm for maximum life-cycle in a network.

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Simulation Parameters: The network set up uses the following simulation parameters mentioned in the table 1.

FIELD AREA	100X100 METER SQUARES
NUMBER OF NODES IN THE FIELD	100
OPTIMAL ELECTION PROBABILITY	P=0.1
INITIAL ENERGY OF NODES	0.5 J
ENERGY CONSUMPTION OF TRANSMIT AND RECEIVE AMPLIFIERS	500 NANO JOULES PER ROUND
MAXIMUM NUMBER OF ROUNDS	5000
DISTANCE BETWEEN CLUSTER HEAD AND BASE STATION	38.25 M
DISTANCE BETWEEN CLUSTER MEMBERS AND CLUSTER HEAD	24.9649 M
F_p	FINITE FIELD, P IS THE LARGE PRIME NUMBER(>210 BITS)
$\boldsymbol{E_p(a,b)}$	ELLIPTIC CURVE EQUATION
G	CENTRIC PARAMETER OF ELLIPTIC CURVE
N	ORDER OF CENTRIC PARAMETER G

RESULTS & DISCUSSIONS

The results are collected when pso technique is applied in DDEEC protocol. This algorithm have optimized the selection of cluster-heads using fitness function of Particle Swarm Optimization algorithm for maximum life-cycle in a network. The sink and source nodes communicate with each other and maintain the routing with enough residual energy so that clustered structure may claim for maximum lifetime. In this algorithm we have different rounds for the cluster head selection based on threshold energy levels of the given nodes..Fig 5 shows the comparison of no of dead nodes in the network .In ddeec, no of dead nodes starts occurring at 1000 rounds and this number is gradually increasing and all nodes become dead at 3500 round but in PSO based DDEEC no of dead nodes starts around 1200 round and it goes to 4000 round when complete network is totally dead.

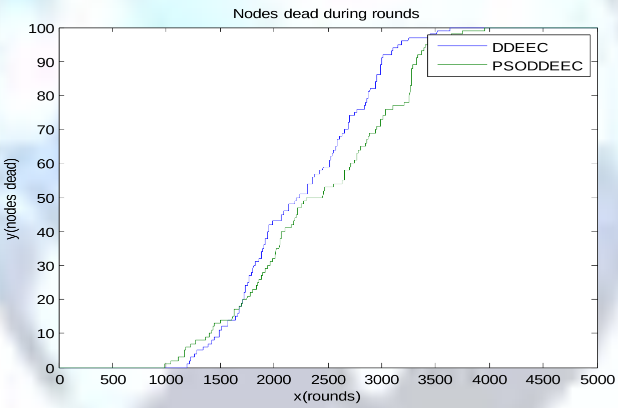

Fig 5: count of no .of dead nodes at different rounds in the network

Fig 6 presents the comparison of no of alive nodes in the network in case of DDEEC and PSODDEEC. Fig 7 shows the comparison of no of packets transferred to the base station in the network. The no of packets sent is very high in case of PSODDEEC as compared to DDEEC and it reaches to 120000 and becomes after 3000 rounds.

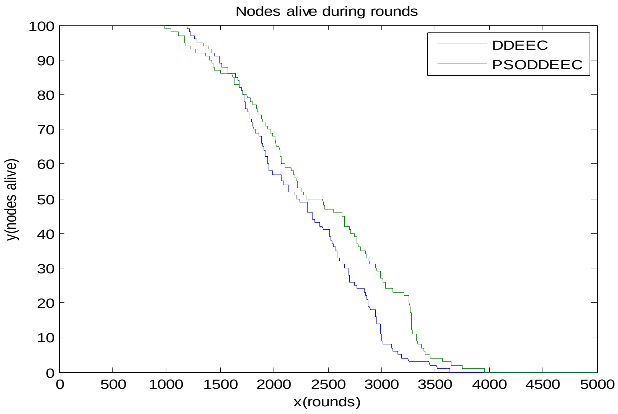

Fig 6: count of no .of alive nodes at different rounds in the network

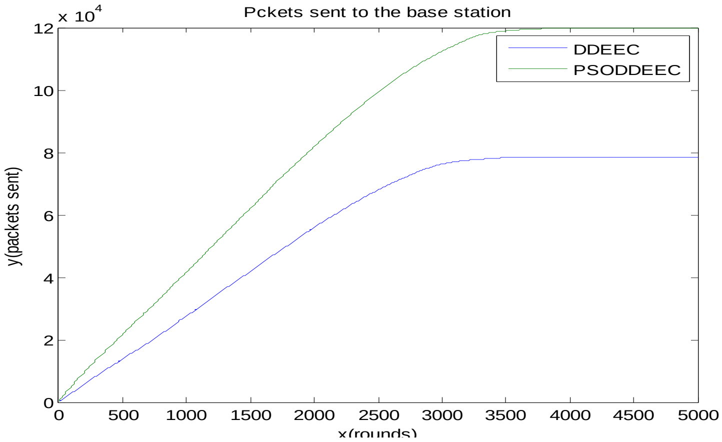

Fig 7: No .of packets sent to the base station in the network

Fig 8 shows the cluster heads formation at different rounds in both the clustering protocol. Clustering technique is good when there is less fluctuation at varying rounds. There is very high fluctuation in DDEEC cluster formation as compared to PSODDEEC. Fluctuation is somewhat constant in PSODDEEC and it suggest that network is more efficient in PSODDEEC.

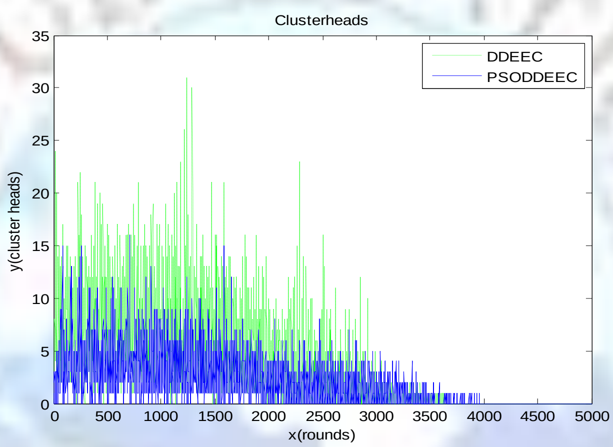

Fig 8: Cluster Head Formation at different rounds in the network

CONCLUSION

Maximization of network life time, high Packet flow is achieved in different rounds of the network in through the Optimization of PSO technique. DDEEC protocol is used for energy efficient clustering. In particular, PSO based DDEEC have been proposed and have been evaluated for the network lifetime and clustering. This algorithm have optimized the selection of cluster-heads using fitness function of Particle Swarm Optimization algorithm for maximum life-cycle in a network. The packet transfer rate at base station reaches a high level when the rounds are increasing in PSODDEEC and becomes constant. The PSO based heterogeneous network is more efficient and it maximizes network life.

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