

# Improved Particle Swarm Optimization for Energy Efficient Clustering and Routing of Wireless Sensor Networks

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## ABSTRACT

The focal inadequacy of modern wireless sensor networks is constrained energy resources of sensors. Therefore, Energy efficient clustering techniques and routing algorithms must be deployed to intensify the durability of wireless sensor networks. The research of an improved particle swarm optimization method for wireless sensor networks is presented in this paper. In order to conquer the inadequacy of the standard particle swarm optimization, improved means for clustering and routing are adopted. To demonstrate the efficiency of the proposed algorithm, a selected set of results are compared with the results of standard particle swarm optimization and genetic algorithm. Simulation outcome proves that the advanced capability of the proposed algorithm is more energy efficient and improved in the quality of service as compared to particle swarm optimization.

**Keywords:** Clustered and routing algorithms, wireless sensor network, energy efficiency, particle swarm optimization, improved particle swarm optimization.

## I. INTRODUCTION

Wireless Sensor Networks (WSN) are extensively used in applications like area monitoring, health care monitoring, environmental sensing, air pollution monitoring, machine health monitoring, forest fires detection and many more [1]. Energy efficiency is an imperative problem in the design of WSNs. The WSNs are made up of huge number of sensor nodes and the distribution depth is more especially when estimated using limited energy of sensor node [1]. Therefore, accurate data transfer must be achieved with higher energy efficiency and increased network lifetime. Smart sensor technology and advances in low power electronics have allowed the development of less energy consuming wireless sensor networks. But clustering and routing algorithm always play a significant role in minimizing energy consumption [2]. In WSNs, sensor nodes are restricted in term of processing power, communication bandwidth, and storage space which demand efficient resource utilization [2].

Group of sensor nodes are formed based on specific rules called as clusters. Clustering is employed in WSN to increase network scalability and efficient use of resources. Clustering minimizes the energy consumption and comprehensive communication overhead [3]. A routing protocol is defined to communicate between base station, cluster head and sensor nodes of the cluster. A large cluster will exhaust cluster head and small cluster size will increase number of cluster and communication delay. Therefore optimal clustering and routing technique is required to have a better energy efficient WSN without compromising quality of service [4]. Different routing and clustering algorithms are used in order to save energy and enhance network lifetime [5]. Among many algorithms, the standard genetic algorithm, its versions and particle swarm optimization are the utmost used and researched techniques. In this paper an improved and more efficient methods is proposed. Comparison study with results will give a detailed knowledge. Rest of the paper is

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organized in the following structure; Section II Particle swarm optimization, Section III Proposed method, Section IV Simulation results and comparison and lastly Section V Conclusion.

## II. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is evolved from swarm intelligence [6]. PSO is the result of the research on bird, fish flock and other animal's activities in search of food or shelter [7]. The PSO is a mathematical computation technique that optimizes a problem. It is done iteratively by trying to ameliorate a candidate solution while maintaining a specified quality. The PSO includes a population of the candidate solutions which primarily called as the particles. These particles are enthused in the search space using mathematical functions. These functions are based on particles position and velocity [8]. Particles motion is dependent on their local best known position but, they are directed toward the finest known positions in the search space. Best possible position is updated until the better and better positions are searched. In this way the swarm move toward the best solutions. An extensive use of PSO application in optimization of WNS are made in [9],[10],[11],[12]. PSO is a meta-heuristic algorithm because only few or no assumptions are made. The PSO algorithm is shown in fig. (1).

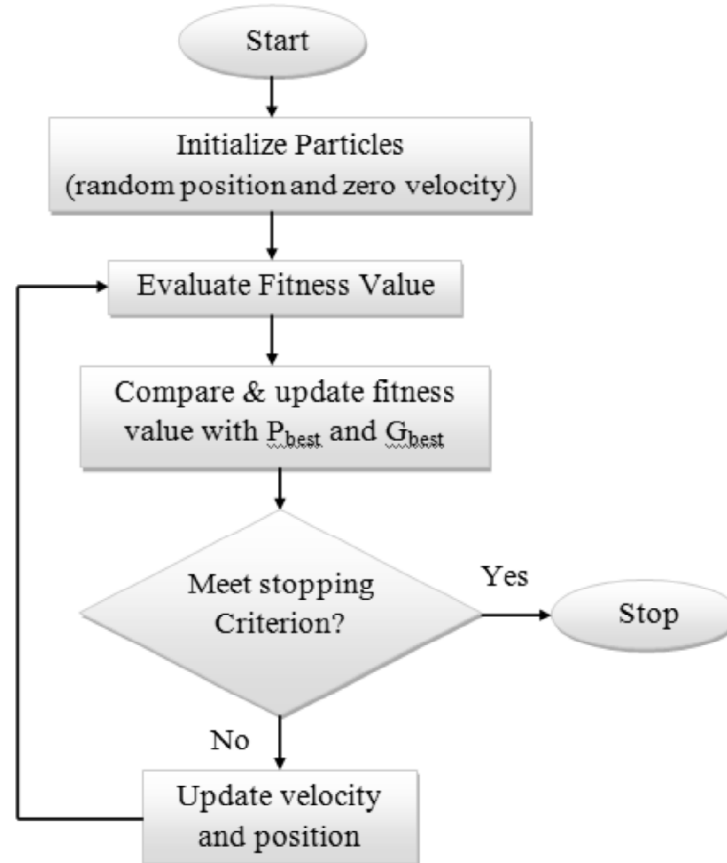


Figure 1: Flowchart of the Particle Swarm Optimization

When a fitness better than the individual best fitness is found, it will be used to replace the individual best fitness. Let assume PSO consists fixed number of particles. Each particle gives a complete solution to  $D$  dimensions.  $N$  particles of population  $P_i$  in the  $d^{\text{th}}$  dimension of the hyperspace has velocity  $V_{id}$ , and position  $X_{id}$ . Global best is denoted as  $G_{best}$  and Personal best is denoted as  $P_{besti}$ . Velocity and position are upgraded in each iteration. Position  $X_{id}$  and velocity  $V_{id}$  are updated in  $d^{\text{th}}$  dimension using equations (1), (2):

$$V_{id}(t) = w \times V_{id}(t-1) \times r_1 \times (X_{pbestid} - X_{id}(t-1)) + c_2 \times r_2 \times (X_{gbestid} - X_{id}(t-1)) \quad (1)$$

$$X_{id}(t) = X_{id}(t-1) + V_{id}(t) \quad (2)$$

Where,  $w$  is the weight function,  $c_1$  and  $c_2$  are two constants called acceleration factor.  $r_1$  and  $r_2$  are two different uniformly distributed random numbers in the range  $[0,1]$ . The updating progression is iteratively continued until an acceptable  $G_{best}$  is attained or a fixed number of iterations  $t_{max}$  are achieved.

The PSO method which uses swarm intelligence is far from simulated annealing (SA) approach and the Genetic algorithm (GA). The POS has no explicit mathematic establishment and no systematically computation method. Only the fundamentals about mechanical principle of PSO are sufficient to employ. The proof of robustness and convergence are explained in the mathematical foundation [13], [14]. PSO can be united with the other intelligent optimization methods to design several compound optimization methods [15]. An improved PSO algorithm is proposed for WSN in next section to overcome its limitations.

### III. PROPOSED METHOD: IMPROVED PSO

Original PSO approach is to optimize the solution using global best and there is chance to be trapped in local area. [16] No suggestion is provided for such situation. As the algorithm considers the best value found by neighbours it is more efficient for small number of particles. As the number of particles increases,  $G_{best}$  version is more beneficial. A modified particle swarm optimization works better but only applied to specific application. The best solution to advance the presentation of the standard PSO algorithm is to attain an efficient balance between exploration and exploitation of particles in swarm [17]. A fundamental scheme is to maintain the diversity of both local and global optima. This point is realized by an incredibly expected way and that is to randomly “perturb” these optima at present iteration. The perturbations are employed in standard PSO just to differentiate between the particle position and the local best solution [17]. Again perturbations may be used to differentiate between the particle current position and the current global best solution. A disadvantage of this system is its confining the exploration capability of particle swarm to widen the exploration capability of particle swarm. Here a proposition is made that the perturbations ought to be straightforwardly employed to the global best solution and the local best solution accomplished so far. Now Such type of perturbations may be created by applying Metropolis algorithm (MA).

However, a probability density function (PDF) may greatly increase the computational complexity of PSO algorithm. Therefore, in this paper, a simple way to generate random perturbations as in the standard PSO algorithm is adopted. The second objective in developing our improved PSO algorithm is to advance the convergence process of the particles in swarm such that all the particles are prevented from flying far away from the feasible search space. IPSO has an algorithm with a growing population that is adopted from incremental social learning (ISL) techniques. The ISL methodology is generally employed to enhance the scalability of systems for which multiple learning agents are inevitable. This technique is used to boost the performance of PSO so that a guaranteed global solution is achieved. The search process grows to be faster with lesser possibility of being trapped into local solutions. The rule used for growing population is given in (3):

$$X'_{new} = X_{new} + U.(P_{model} - X_{new}) \quad (3)$$

$X'_{new}$  = The new particle's updated position

$X_{new}$  = The new particle's original random position

$P_{model}$  = The model particle's position

$U$  = A uniformly distributed random number in the range  $(1,0)$ .

The topology model ( $P_{model}$ ) used in this paper is global best model. So the updating  $X_{new}$  each iteration ( $k$ ) can be described.  $X_{new}$  can be added anytime (at schedule time), Once  $X_{new}$  is added to the population, it is also needed to update each iteration. The flowchart of the IPSO is shown in Fig. 2.

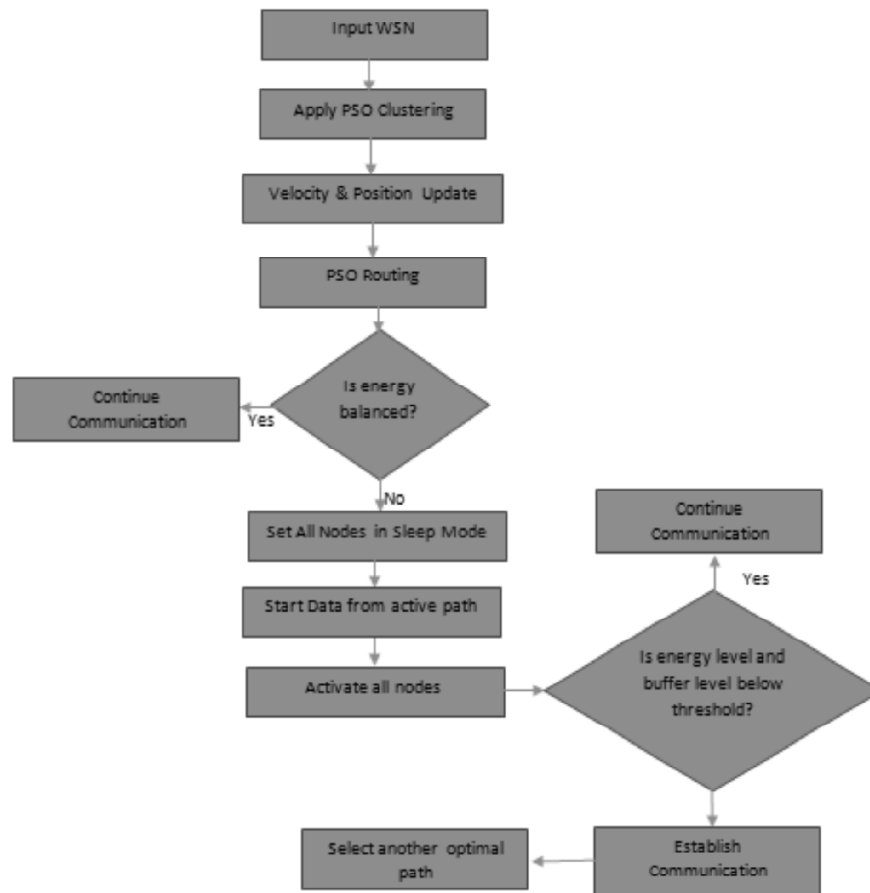


Figure 2: Flowchart of the Improved PSO Algorithm

We are presenting the improved PSO method to solve the problem of unbalanced energy consumption as well as improving the efficiency while deploying the sensor nodes. Efficiency and Energy consumption is minimized by adding below steps before sending data from source to destination nodes. When any of the source nodes (either cluster head or sensor node) wants to send the data, that node should activate the path through which data is going to be sent. When energy level of any node (either cluster head or sensor node) goes below threshold, as given by its parent, or congestion is detected at that node then, that node informs its parent. Parent will find another path towards destination. When any node detects all its lower depth nodes below current threshold value, it calculates new threshold and, Start sending data on those paths again.

## V. SIMULATION RESULTS AND COMPARISON

### (A) Simulation Scenario

Simulation of all algorithms is carried out in NS2. NS2 is stand of the Network Simulator Version 2 which is targeted specially for the networks simulations. NS2 is nothing but the discrete event simulator for the researches in the area of networking. The NS2 supports all wired, wireless networks. It supports TCP, UDP and CBR forms of the communications. NS2 is made of two parts basically such as NS means network simulator and other one is NAM means network animator. The simulation is carried out in different scenarios and they are listed as follows:

Routing Protocols: GA, PSO and IPSO (Proposed)

Network Conditions: Sensor network

Number of Sensor Nodes: 200,300,400,500,600,700.

Number of Gateways: 90

MAC: 802.11

### (B) Comparison Parameters

The comparison of these three algorithms is done using five performance parameters and which are energy consumption, packet received, network lifetime, end to end delay and throughput.

- 1) Packets Received: It is the calculation of the ratio of packet received by the destinations to the packets sent by various sources.
- 2) End to end packet delay: This metrics calculates the time between the packet origination time at the source and the packet reaching time at the destination. Such kind of metrics we have to measure against the different number of nodes, different traffic patterns and data connections.
- 3) Energy Consumption: The metric is measured as the percent of energy consumed by a node with respect to its initial energy. The initial energy and the final energy left in the node, at the end of the simulation run are measured. The percent energy used by each node is calculated as the ratio of energy consumed to the initial energy. Finally the percent energy consumed by every node in a situation is computed as the average of individual energy consumed by each node.
- 4) Network Lifetime: The Network lifetime simply represents the lifetime of sensor nodes forming a network which are performing their desired work optimally. It is counted in hours and plays a major role.

### (C) Results and Comparison

#### 1) Results for 90 Gateways:

The comparison of five algorithms for 90 gateways is shown in Fig. 3, Fig. 4, Fig. 5, Fig 6, Fig 7. The energy consumption is minim for proposed IPSO method than PSO and GA though number of gateways are increased. Highest network lifetime is also achieved. IPSO has higher packet recovery performance if the number of gateways are increased, while maintaining lower energy consumption and higher network lifetime. It has been also seen from analysis that End to End delay is minimized by 20 % on an average and IPSO gives approx. 38% better performance than PSO.

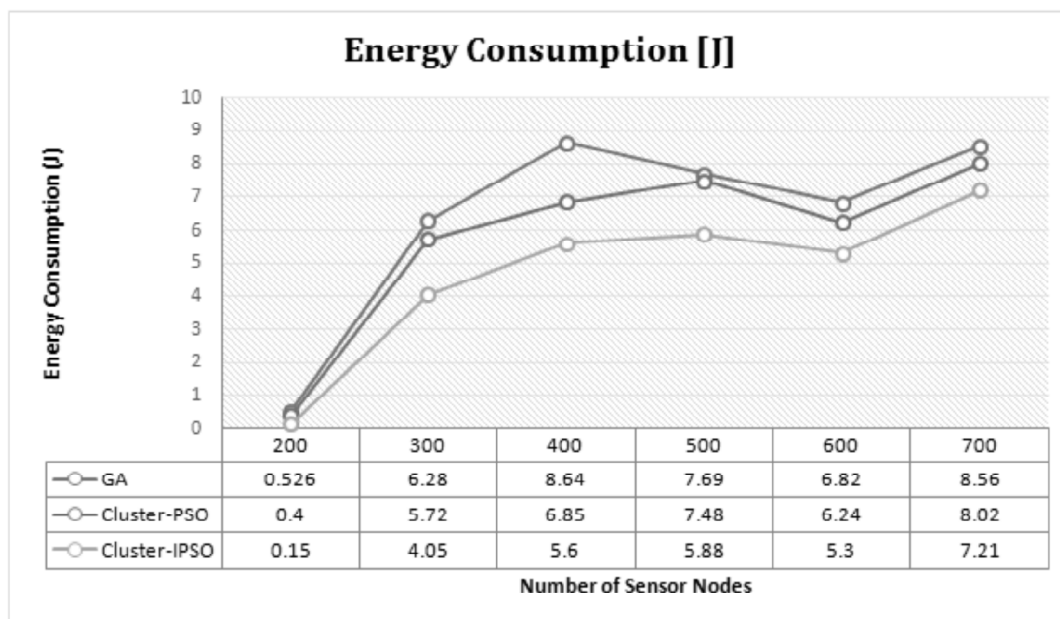


Figure 3: Average Energy Consumption (90 Gateways)

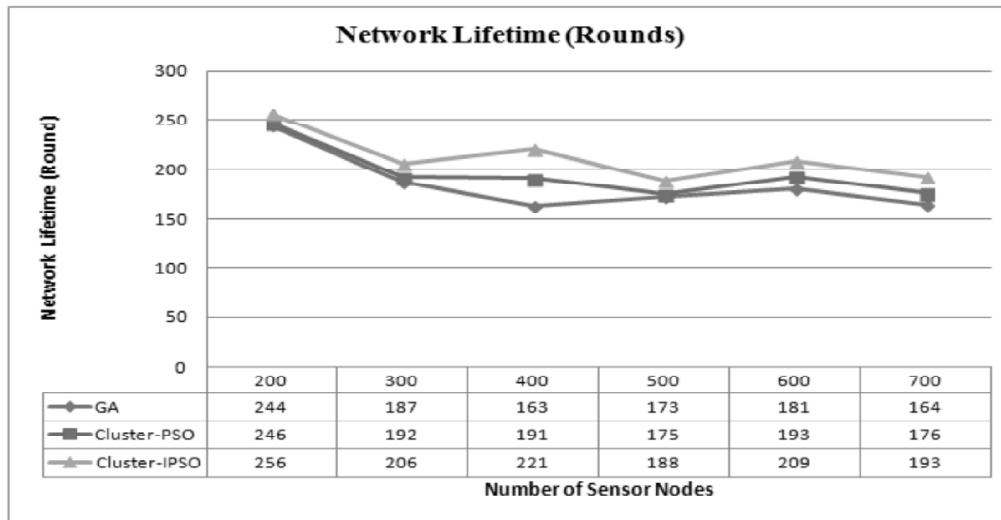


Figure 4: Network Lifetime (90 Gateways)

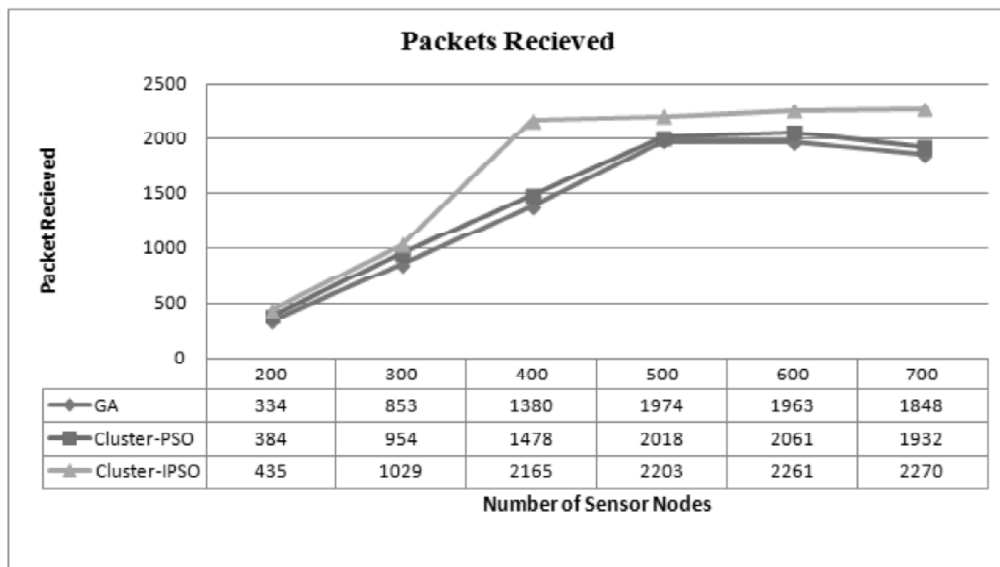


Figure 5: Packet Received (90 Gateways)

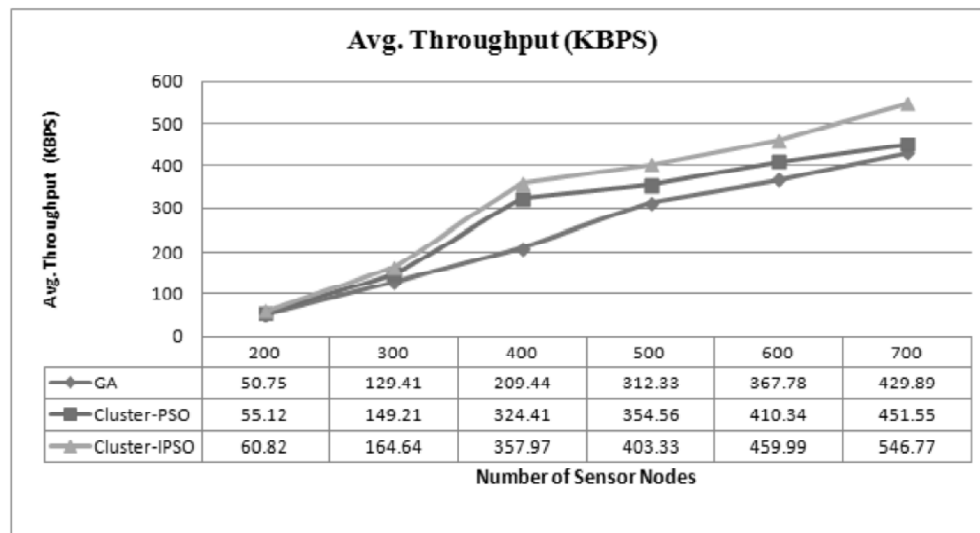
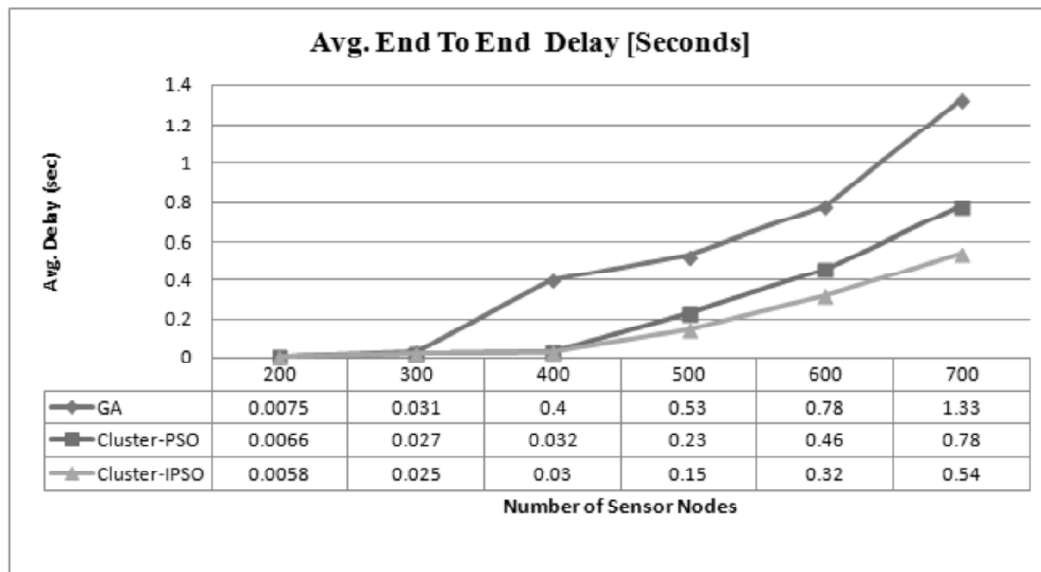


Figure 6: Average Throughput (90 Gateways)



**Figure 7: Average End To End Delay (90 Gateways)**

## V. CONCLUSION

Energy consumption is an important and scarcest element in application of clustering and routing protocols for WSNs. In this paper We are presenting the improved PSO method to solve the problem of unbalanced energy consumption as well as improving the efficiency while deploying the sensor nodes. High quality of service should be attain as networks are handling very sensitive data. For comparison, simulation results of all three algorithms GA, PSO and IPSO are obtained in different network scenarios. Results shows that proposed method reduces energy consumption, increases network lifetime, increases packet recovery also increases the average throughput and minimized the end to end delay as compared to the standard GA and PSO algorithm. It is absolutely clear that if the network is large in size having more number of sensor nodes and gateways then this proposed algorithm achieve highest performance.

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