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Development and Analysis of IoT based Smart Agriculture System for Heterogenous Nodes

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Abstract*— The Internet of Things (IoT) integration with wireless sensor networks (WSNs) used in various applications like smart cities, smart transportation, smart agriculture and real-time monitoring of industrial activities. The application of IoT-WSN is increasing day by day for different applications. For optimization of the crop quality various sensor nodes equipped with specific sensors like Soil, Temperature and Humidity sensor, Ultrasonic sensor to get signal about vertical growth of crop, Co2 sensor are randomly distributed across agriculture land. But, conventional WSN nodes have limited amount of energy that exist in sensor nodes. Recharging and replacement of the batteries at the sensor nodes becomes a difficult task. Heterogeneous sensor nodes placement provides many possibilities because of their sensing range and diverse computing power. The sensor node deployment, network connectivity, power consumption, coverage area and network lifetime are the primary issues in WSNs which need to be addressed. So, in this paper, our primary objective is to use intelligent deployment strategy for sensor node placement in IoT-WSN enabled smart agriculture (I-WSA) by using analytical algorithm like Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) to minimize energy depletion of sensor nodes to prolong network lifetime using direct routing protocol and multi-hop routing protocol. Experimental results depict that the network lifetime can be increased up to an average of 140-150%. In the paper there is a comparison of GA and PSO. The benefit of heterogeneous networks has been explored in our paper through experimental results.

Keywords-- Internet of Things, Wireless Sensor Networks, Smart Agriculture, Multi-Hop Routing, Heterogeneous Nodes, Network lifetime

I. INTRODUCTION

With the rapid growth of human population globally, there is always increasing demand for farmland, water and other natural resources to fulfill the daily needs of large populations. Also, varying environmental conditions results in big challenges among the farmers to maintain better crop yield and sustainable agriculture [1]. From last few years, a latest technology has emerged which changed our lifestyle rapidly called internet of Things (IoT) in which several physical objects called devices are interconnected with each other. IoT enabled system is most essential in the applications like home automation, smart agriculture, smart transport, disaster management and rescue operations, security and monitoring etc. [2]. These IoT applications depend on reliable and real-time collection of data from various energy-efficient wireless sensors [3]. An international data corporation (IDC) forecasts up to 45 billion IoT enable devices by 2025 with a potential to generate data up to 79.4 ZB [5]. IoT integration with WSN provides a new approach to farmer for increasing productivity in farming. Wireless sensor networks (WSNs) consist of a huge quantity of sensor nodes which randomly distributed over large area and sense signals or capture data through integrated sensors and send the collected data to base station as shown in fig. 1. Data like PH of soil, CO2 concentration, temperature and humidity of the land environment which is collected by wireless sensor nodes increase the productivity of soil. An important factor that is associated with WSNs is the limited amount of energy that exists in sensor nodes as they use batteries small in size, and it is difficult to charge again or bring new battery frequently. So, it is important that each node in WSN consumes less energy for data gathering and transmission. To minimize the problem of energy depletion at power hungry sensor nodes and increase network lifetime, routing protocols should have low node energy consumption and more energy-efficient [7]. IoT-WSN enables smart farming depending upon data gathering from various sensor nodes spans in large area. WSN gives smart solutions to farming for collection, propagation, and processing of gathered data. So, the minimization of consumption of energy of these wireless nodes had always been a matter of concern among the researcher community [8].

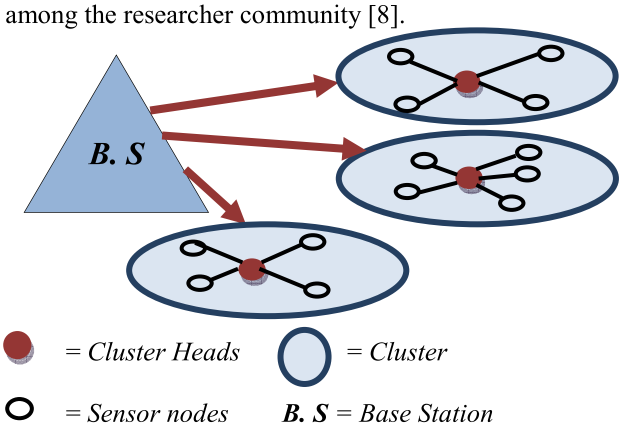


Fig. 1. Sensor nodes network

Fig. 1 depicts nodes are clubbed into clusters and more than one node worked like CH i.e., cluster heads to gather data in the clusters, fuse them and pass to the sink node. The use of WSN using IoT can provide more efficient and reliable farming [17]. The incorporation of WSN with IoT for smart agriculture to be fruitful in the 21st century for the optimization of crop field [19]. The deployment of sensor nodes in smart agriculture is a crucial strategy which directly influences the performance of IoT-WSN. Some of the nodes are randomly deployed while some of them deployed through planned manner. WSN are in remote locations such as woodland, mountains, deserts and military areas, their sensor nodes are powered by AA batteries which has limited life span. The term network lifetime described as a time in between first node deployment dead till end node in the network dies. The battery used in WSN is non-rechargeable so when battery of a particular sensor node dies, it directly affects the system execution. Thus, we have used intelligent deployment strategy for heterogenous nodes using mathematical methodologies like Genetic Algorithm (GA) and Particle swarm optimization (PSO) to assess our system execution in terms of network lifetime, energy consumption and efficiency etc.

II. SMART AGRICULTURE

The term Smart agriculture is related to a use of Information and Communication Technology in modern way of farming which employ smart techniques like Internet of Things, Big Data, Cloud Computing, Wireless Sensor Networks, Robotics, Artificial Intelligence and Machine learning algorithm in our farmland to optimize the performance of the network.

Smart agriculture is becoming widely known concept enables the use of modern technologies like IoT, AI, ML,

Fig. 2. *IoT for Smart Agriculture use cases [1]*

drones and robotics etc. to increase better crop yield and attain maximum output from input while optimizing the required human labor for production. Smart agriculture is associated with advanced information and communication technologies for better production with existing practices of farming.

Fig 2. Represents the applications of smart agriculture in precision farming, forest monitoring, data analytics, tracking and tracing etc.

A. *Smart Agriculture Model*

Fig 3. Represents the smart agriculture model equipped with specifics set of sensors. These sensors are placed according to our applications and basically used for capturing of data from farm land and through data processing, better assessment of the crop quality can be carried out. Its use ICT techniques for the performance analysis of the system.

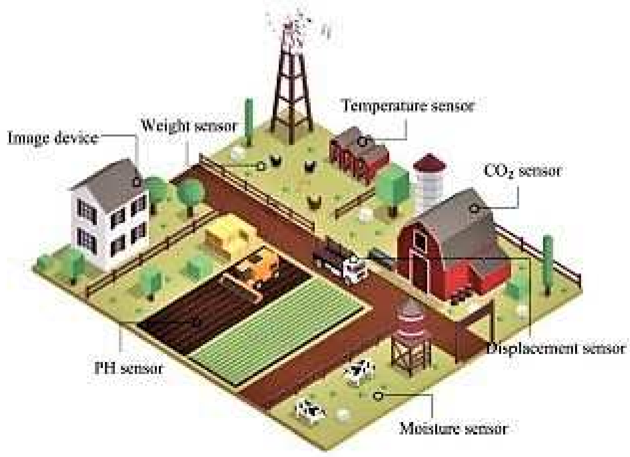


Fig. 3. *Smart Agriculture Model [8]*

B. *IoT-WSN based Smart Agriculture*

Fig 4. Shows IoT-WSN based Smart Agriculture (I-WSA) system in which various sensor nodes are deployed across large region for real-time data gathering and through internet connectivity transferred it to end user for performance analysis of acquired data.

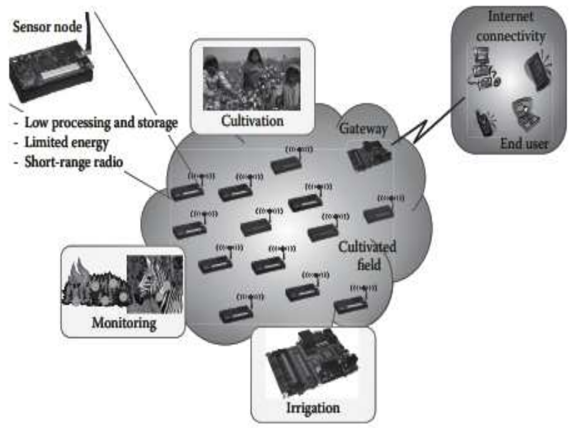


Fig. 4. *IoT-WSN based Smart Agriculture [10]*

III. RELATED WORK

Quy *et al.* [1] presents a survey of IoT integration with enabled technologies like WSN, cloud computing, big data etc. The author discusses recent technologies and opportunities of IoT enabled smart agriculture framework development. The author also highlights the typical applications of IoT-WSN in smart agriculture like monitoring farms, precision farming, drone farming, tracking, monitoring, and data analytics etc. Challenges and open issues like economic efficiency, reliability, degradation of soil quality have been discussed by the author. Xu *et al.* [2] discussed the energy consumption minimization problem by wirelessly powered IoT sensors in the process of collection of data. Author simulation results validate energy-efficient data gathering by IoT sensors. Mahmoudi *et al.* [3] presents energy consumption minimization using quantum-inspired clustering. Through simulation results 15.48% IoT nodes energy can be saved by using this technique. Gavali *et al.* [4] used swarm intelligence for energy consumption optimization in underwater Wireless sensor network. Through simulation results average energy consumption reduced by 8.45% Xiao *et al.* [5] show that energy consumption can be minimized by using adaptive elite ant colony optimization (AEACO) by 30.2% in comparison to genetic algorithm (GA) and 23.4% when compared to particle swarm optimization (PSO). Anjus *et al.* [6] discussed time and energy minimization scheduler (TEMS) to minimize utilization of energy by 52.1 % and improved task completion time by 85.9%. Jin *et al.* [7] presents spanning forest algorithm in WSN enable system to reduce energy consumption. Simulation carried out through NS2 simulator and results show that consumption of energy at sensor nodes may be decreased and network lifetime increases using proposed mechanism. Lu *et al.* [8] proposed SWIPT enabled WSNs for smart agriculture systems to optimize the performance in terms of energy efficiency of the system. Agarwal *et al.* [9] proposed residual energy based enhanced duty cycling algorithm to optimize the performance for energy dissipation at sensor nodes and throughput of IoT enabled precision agriculture. Muruganandam [10] highlights issues in duty cycling and suggested some algorithms to assess the network lifetime performance and dissipation of energy. Ahmed *et al.* [11] emphasis on enhanced multi-hop routing protocol for energy optimization. NS2 simulator result of the proposed system shows improvement in system optimization as compared to existing protocols. Nivedhitha *et al.* [12] presents dynamic and sustained multi-hop routing protocol in WSN to maintain reliability of path and energy optimization. NS2.33 simulation results show that through this approach there is a significant reduction in energy consumption, packet delivery and network lifetime has also increased. Fathallah *et al.* [13] presents partition aware IoT routing protocol for energy optimization in smart agriculture. Through RA-RPL 40% of energy consumption can be saved. Prodanovic *et al.* [14] proposed enhanced model of data security which can be utilized for data protection and simulation results demonstrated that the efficiency of the system can be enhanced by deploying data security model. Haseeb *et al.* [15] demonstrate an IoT-WSN framework to optimize energy up to 16%. The suggested framework adopts a single-hop approach for transmission of data and used residual energy between BS and CH. Rishiwal *et al.* [16] presents a protocol i.e. QOS-based optimized energy clustering routing (QOS-CR) to assess and analyze dissipation of energy in IoT -WSN system and through MATLAB simulation 35-40% energy consumption can be minimized. Sanjeevi *et al.* [17] have suggested smart irrigation system for precision agriculture and farming (SIS-PAF) under this different sensor deployed in the farming land. The simulation part substantiated that suggested system gives superior performance as compared to traditional way farming. Saini *et al.* [18] proposed energy efficient GA based method with virtual grid based dynamic routing adjustment (VGDRA) to optimize the wireless sensor networks nodes power consumption. Dey *et al.* [19] experimented proposed system in eastern part of Bangladesh for the crop monitoring using various sensors for the optimization of farming land. Sharma *et al.* [20] have presented solar energy harvesting technique to maximize the lifetime of WSN. Simulation carried out through NS2 simulator used to optimize wireless sensor network lifetime.

IV. COMPARATIVE STUDY AND ANALYTICS

Table. 1. ENERGY CONSUMPTION MINIMIZATION METHODS BY AUTHORS

Author	Methods	Energy Minimization
Xu et al. [2]	DRL-based approach	20%
Mahmoudi et al. [3]	Quantum inspired Clustering method	15.48%
Gavali et al. [4]	Swarm intelligence	8.45%
Xiao et al. [5]	Adaptive elite ant colony optimization	30.7% and 22.5%
Anjos et al. [6]	Time and energy minimization scheduler	51.6%
Jin et al. [7]	Multi-start minimum spanning forest algorithm	-
Lu et al. [8]	SWIPT-enabled system	6-7%
Agrawal et al. [9]	Improved duty cycle algorithm	-
Ahmed et al. [11]	Enhance multi-hop routing protocol	-
Fathallah et al. [13]	Partition Aware-RPL	40%
Prodanovic et al. [14]	Data security model	1.3%
Haseeb et al. [15]	Energy and link efficient routing protocol	16%
Rishiwal [16]	QOS-based optimized energy clustering routing protocol (QOECR)	35-40%

Table 1 shows comparative study for energy minimization by varius authors through our literature review.

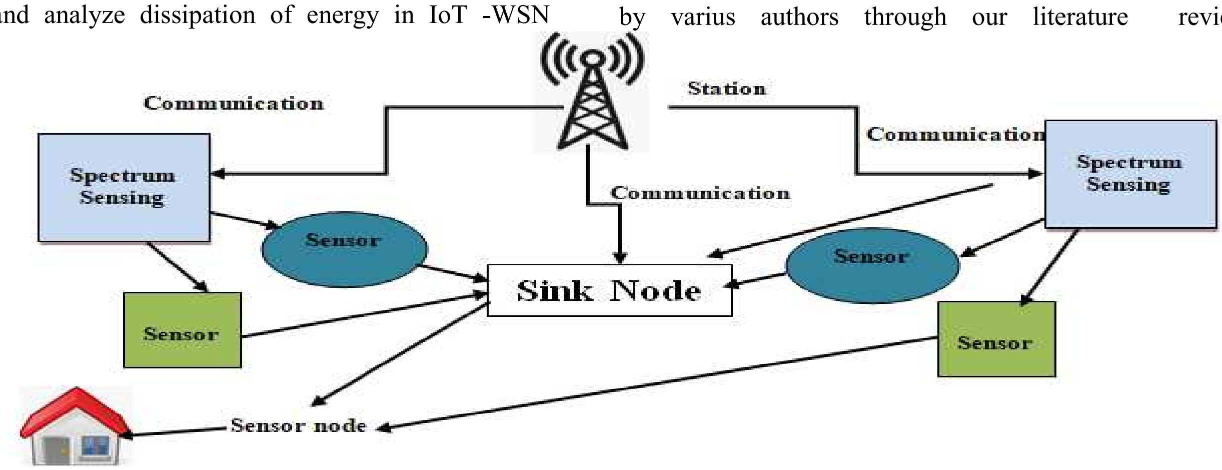


Fig. 5. *Energy consumption minimization WSN proposed mode*

V. THE PROPOSED ENERGY CONSUMPTION -WSN MODEL

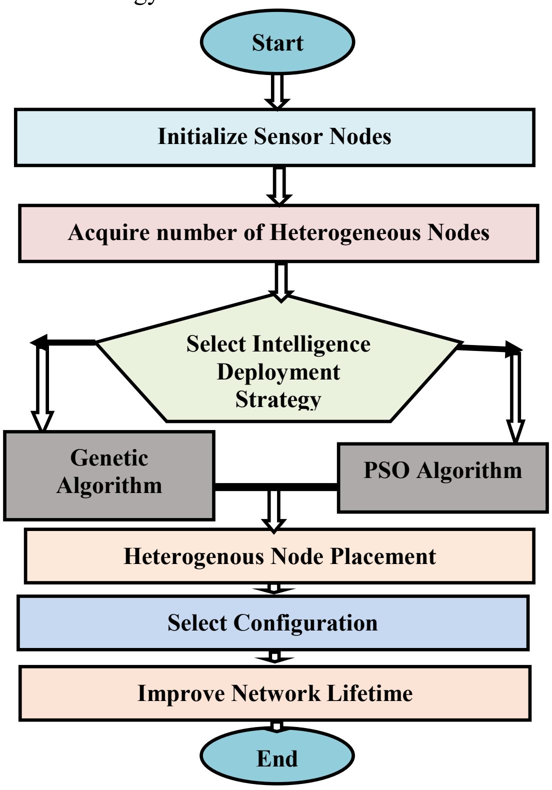
Fig. 5. Explained the architecture of our proposed energy minimization WSN model in which sink node get communication to spectrum sensing module through base station and home gets communication through sensor nodes.

VI. OBJECTIVES

Main objective of this paper is to discuss on performance optimization of IoT-WSN based smart agriculture system using intelligent deployment strategy for heterogenous nodes using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). Also through our suggested WSN model energy consumption minimization can be performed.

VII. PROPOSED METHODOLOGY

The methodology works like this:



In proposed algorithm first phase will be deployment of sensors to collect data from the environment and then transmission of collected data carried out through LoRa WAN, data analytics and data processing performed at the server and finally results about smart farming provided to farmers for better production.

VIII. ALGORITHM

We have utilized two mathematical methods Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for evaluation of the system. These two methods are widely used for constructing planned and re-deployment for WSNs nodes.

A. Genetic Algorithms (GA) :

GAs algorithm is based upon search and optimization techniques, developed by John Holland's in the early 1970s and used in computer networking, artificial intelligence and machine learning algorithms. The concept of GA is based on Darwin's theory of node selection, which states that "species whose individuals are best adapted survive; others go extinct." GAs is useful in stochastic optimization techniques.

1) Genetic Algorithm Process

Set t $\longrightarrow$ **0**
Initialize P(t) where P(t) denotes Population of chromosomes (Individuals) at time t
Analyze P(t) - Analyze individuals using a fitness (Eliminate weak members and select fittest members) function.
While (No termination condition)
  Connect P(t) to bring in C(t) (Selection phase i.e., choose individuals to create a new population)
  Evaluate C(t) (Evaluate new population)
  Choose P(t+1) from P(t) and C(t) (iteration process)
  t $\longleftarrow$ **t+1**
End While (Process either end or go to logical solution)

B. Particle Swarm Optimization (PSO)

Particle swarm optimization (PSO) algorithm is based upon dense crowd influenced by social behavior of flying objects, insects, fishes, and birds etc. PSO used a variety of optimization techniques. A group of distributed particles is known as swarm. These group of particles collect resources in a group without collision with each other. There is a collaboration and understanding among these particles and they follow each other. In primary stage of PSO, each particle has given with a random deployment they move in search space. Every particle gives a smart solution for a given statement. The statement is then verified by a fitness function. The particle varies its movement to achieve the best possible solution. This process is iterative and continues to achieve best solution.

2) Particle Swarm Optimization Process

Set t $\longrightarrow$ **0**
Initialize S and put M= S (Assign Random position and velocity)
Evaluate S and M – Provide best solution to problem and set new best position as g
While (No termination condition)
  Update S
  Evaluate S (Redefine g and verified by fitness function)
  Choose P(t+1) from P(t) and C(t) (iteration process)
  t $\longleftarrow$ **t+1**
End While (Process either end or go to logical solution)
Print best position achieved.

IX. SIMULATION RESULTS

We have utilized the hardware and software to run our system.

1) **Simulation platform**- MATLAB R2022b
2) **Operating system**- Microsoft Windows 7

The simulations are carried out assuming random deployment of nodes and through varying number of sensor nodes by considering a single base station. In the simulation, we have used direct transmission and multi-hop transmission separately for GA and PSO. Assume terrain size of 100x100 and around 50 wireless sensor nodes deployed randomly. The cluster heads get packets from its sensor nodes, collect data and transmit them to the sink. The meaning of direct routing protocol is to transmit data directly to sink node. For this, energy dissipation is high. But, in Multi-hop network sensor nodes send data to its nearest node available. Simulation is carried out separately for genetic algorithm and particle swarm optimization for direct transmission as well as multi-hop transmission as shown in figures to optimize the performance of the IoT-

WSN smart agriculture system in terms of network lifetime.

A. Genetic Algorithm

Direct Transmission with 50 sensor nodes and 10 hetrogeneous nodes

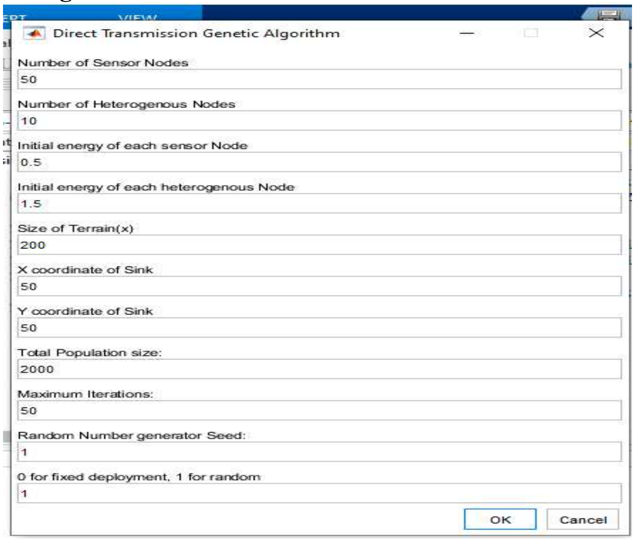


Fig. 6. *GA Direct Transmission Parameters*

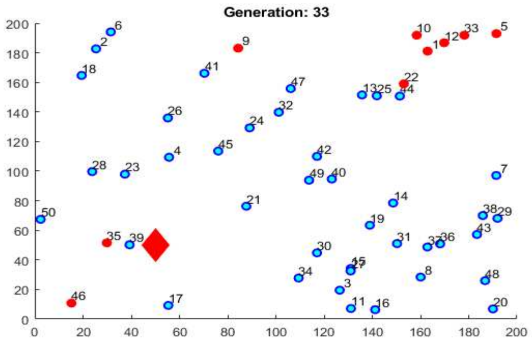


Fig. 7. *(a) GA Direct Transmission result*

Mean Saturation (Direct Transmission)

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Initial Energy : 0.50
Initial Lifetime : 115
Final Lifetime : 362
Time Taken : 121.19 seconds.

Mean Saturation. (Multi-Hop Transmission)

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Initial Energy : 0.50
Initial Lifetime : 1085
Final Lifetime : 1509
Generation : 41
Time Taken : 56.28 seconds.

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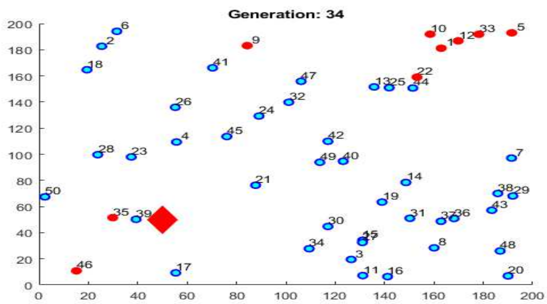

Fig. 8. *(b) GA Direct Transmission result*

Multihop with 50 sensor nodes and 10 hetrogeneous nodes

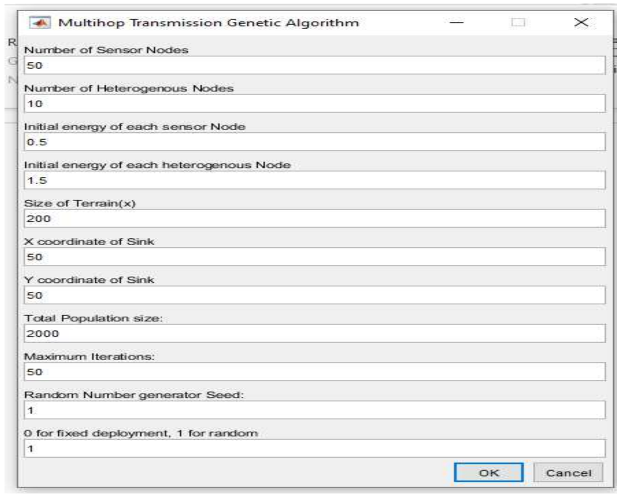

Fig. 9. *GA Multi-Hop Transmission parameters*

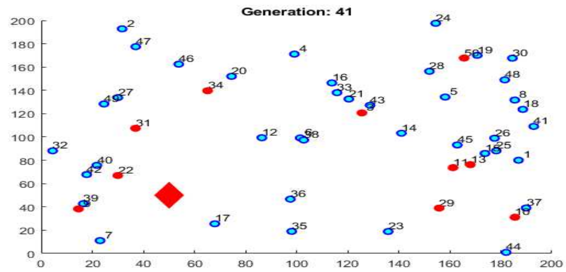

Fig. 10. *GA Multi-Hop Transmission result*

B. Particle Swarm Optimization

Direct Transmission

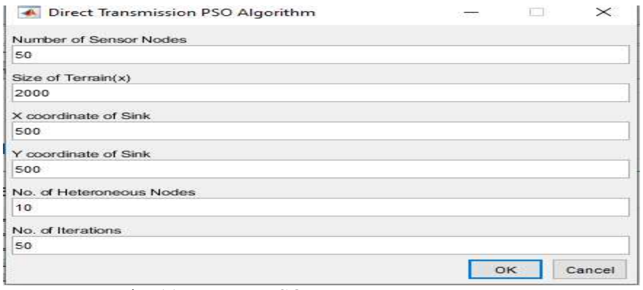

Fig. 11. *PSO Direct Transmission parameters*

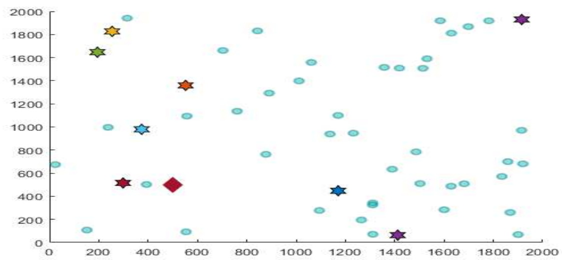

Fig. 12. *PSO Direct Transmission result*

PSO Multi-Hop transmission

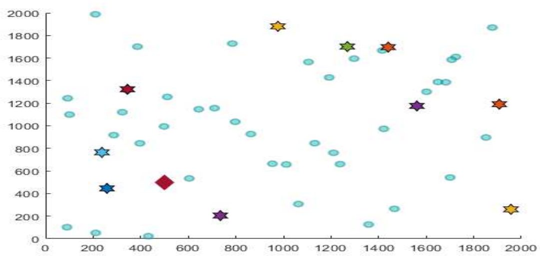

Fig. 13. *PSO Multi-Hop Transmission result*

C. Comparison (GA v/s PSO)

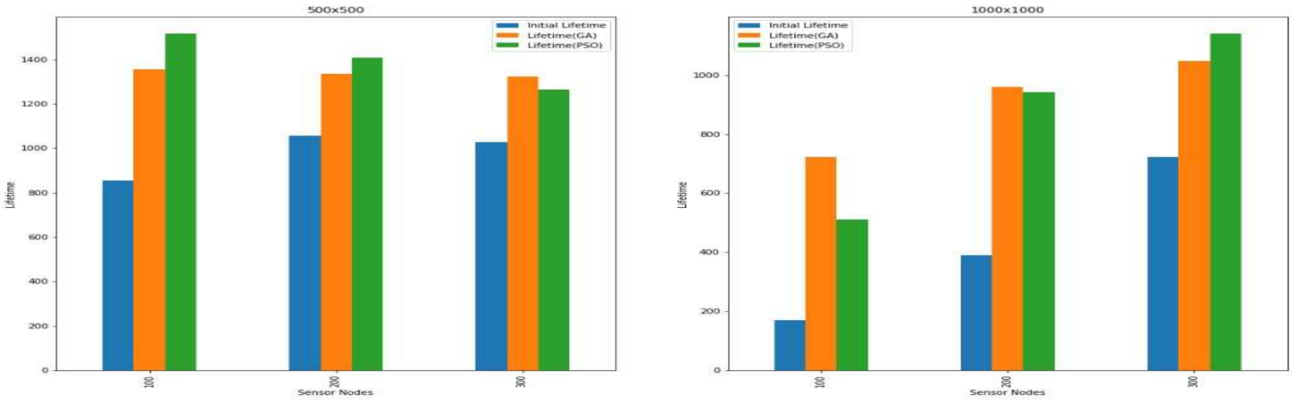

Fig. 14. *Comparison of GA and PSO for lifetime parameter*

PSO slower than GA as shown in fig. 14 and PSO have better performance for big size terrain.

X. CONCLUSION AND FUTURE SCOPE

As a result of the rapid growth in development of smart cities, WSNs have a crucial role in our day to day lives. When sensor nodes are spread and they require to stay active for data collection and send it from remote location, deployment issues in WSNs become crucial. A maximum amount of wireless sensor nodes is required to be placed in open agriculture land for data acquisition.

This paper proposed an energy efficient IoT-WSN prototype experimented by using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). From the experimental results, it is substantiated that both GA and PSO are useful to optimize the performance of wireless networks and they can maximize the network lifetime on average up to 140%-150%. PSO is moderate because it is based on sequential calculation. From simulation, we can observe that both the algorithms are used to maximize network lifetime. But the percentage of network lifetime may increase, if the terrain size of networks has deviation from its neutral value.

As a future scope, we wish to analyze the system performance in terms of some other parameters like throughput, latency, residual energy, stability period and packet delivery ratio etc. using other simulation tools available such as NS2, NS3, OMNET+ and CONTIKI etc.

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