JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 08, 2020

PARAMETER AWARE SENSING CLUSTERING (PASC) PROTOCOL FOR WIRELESS SENSOR NETWORK FOR APPLE CROP MONITORING

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Received: 11.03.2020 Revised: 12.04.2020 Accepted: 28.05.2020

Abstract

Wireless Sensor Network (WSN) is a network formed of energy constrained tiny nodes deployed for the monitoring of temperature, humidity, water level, leaf wetness in an agricultural application scenario. Aggregating and transmitting the sensed data to sink and other communication overheads require a high amount of energy. For this cause, various hierarchical or cluster-based routing approaches have been proposed to offer efficient solutions for reducing the energy dissipation and increasing the lifetime of the network. Cluster-based methods use some nodes as Cluster Heads (CHs) which receives and forwards the information collected from member of that cluster to the base station. CH selection in WSN is NP-Hard as optimal data aggregation with efficient energy savings cannot be solved in polynomial time. In this work, a novel protocol for parameter aware sensing clustering approach and GSA-based (Gravitational search algorithm) data routing, called Parameter Aware Sensing Clustering (PASC) protocol is proposed to improve the network performance and enhance network lifetime in application specific deployment. The study was carried out to monitor the Apple crop environmental parameters, that play a vital role in the development of scab infection, for farmers of Kashmir valley. Extensive NS2 simulation shows that PASC protocol performed well compared to LEACH, PEAL and FIREFLY. Simulations show the effectiveness of the proposed method in increasing the lifetime of the network by more than 50% and improving the energy efficiency of the network when compared to LEACH, PEAL and FIREFLY.

Key words: Advisory System, Apple Scab Monitoring, Cluster-based Routing, Gravitational Search Algorithm (GSA), Wireless Sensor Monitoring (WSN).

1. Introduction

Latest developments in micro-electromechanical systems (MEMS) and small power architectures has contributed to the development of economic tiny-sized battery-operated sensors that have computational as well as communication capabilities which has revolutionized the world of WSNs, thus influencing a fairly large chunk of society [1]. WSNs a group of thousands of /assembly of various number of battery-operated autonomous sensor nodes distributed over an area of interest and operating in a collaborative way to execute a given task. Each sensor node gathers the data/information from its region of interest, processes the data and forwards them to the base station (BS) [2]. WSNs have emerged as an excellent choice for use in the area of agriculture, health care, environment, home automation and livestock etc. The process collecting, processing and communicating the information within the deployed networks base station consumes the battery power and drains the network slowly to death. Thus, efficient consumption of energy in WSNs is one of the most critical and researched issue. This limitation requires an innovative strategy for efficient utilization of the power source as well as the communication bandwidth proficient data transfer capacity in the network [3][4]. Efforts have been made to develop and design various routing protocols for sensor networks keeping in consideration the application area of the WSNs. Deployment of sensor nodes over a large area makes it is quite challenging to organize a huge number of sensors, and keep them interacting regularly. So as to accomplish these goals, groups or clusters of sensors formed. Each cluster is governed by a resourceful, elected or a pre-assigned node referred to as the cluster head (CH). Right selection of a cluster head can incorporate efficient management techniques that will further improve the operation of the network and extend the power consumption of the individual sensors and the lifetime of the network [1]. Cluster-based network architectures provide minimal energy consumption, network scalability, routing optimization and reduces communication overheads to the base station, thus making a network more stable. For wireless sensor networks a number of clustering algorithms have been proposed over the last few years [5]. In the clustering mechanism, communication is segregated into intra- and inter- cluster head communication. The optimal chosen CH transfers all the collected information to the base station. CH receives information from other nodes in its cluster or other CHs in a hierarchical manner, aggregates, and routes the data packets from the lower layer cluster to the higher and then directly to the BS as shown in Fig.1. Such process becomes quite complex and unpractical when the size or the deployment scenario is quite large [2]. The decision of choosing an optimal cluster head as well as the routing techniques in large resource constrained network involves a trade-of between energy consumption and performance of the network. In order to attain the trade-off WSN issues including node distribution and placement, energy aware grouping and aggregation of information are considered as optimization problems. With huge requirement of computational power and increase in the size of network, such issues become challenging for classical analytical optimization algorithms [6]. Consequently, the trend shifted on to research focusing on nature inspired strategies (Genetic Algorithm, Particle Swarm Optimization, etc) which have lesser memory and computational requirements however/ but nevertheless provide the optimized solutions to the problems, like energy consumption of an individual sensor node, choice of CH and routing [2].

GSA is one of the higher order optimization algorithms rooted on principals of gravitational laws formulated by Newton. In Gravitational Search Algorithm searcher agents are referred to as objects and the output of agents is determined by their masses. Each object has four features: position, inertial mass, active gravitational mass, and passive gravitational mass Every object pulls in one another by the gravitational force, thus inducing a movement of all agents towards the one with heavier mass. The heavier agents and their location contribute to the optimal solutions inside the search space, with the help of correct adjustments of inertial and gravitational mass using a fitness function. GSA has been used extensively in diverse and complicated real-world problems. With the newer modification to GSA, it out-performed other noted/widely known algorithms like PSO, RGA and CFO [7][8]. The superiority of this algorithm prompted us to propose GSA-Based optimized WSN routing algorithm for the use in monitoring of apple crop. The proposed algorithm expeditiously chooses the optimum sensor as the CH keeping in account the energy constraint for the network's lifetime deployed over an apple orchard for monitoring of apple scab infection in Kashmir valley. In the performance analysis the proposed algorithm is compared some previous techniques. The rest of the paper is organised as follows: Following section presents related literature review. The proposed algorithm will be discussed in detail Section 4.3. The simulation environment and the performance results will be presented in Section 5. Finally, the paper is concluded in section 6.

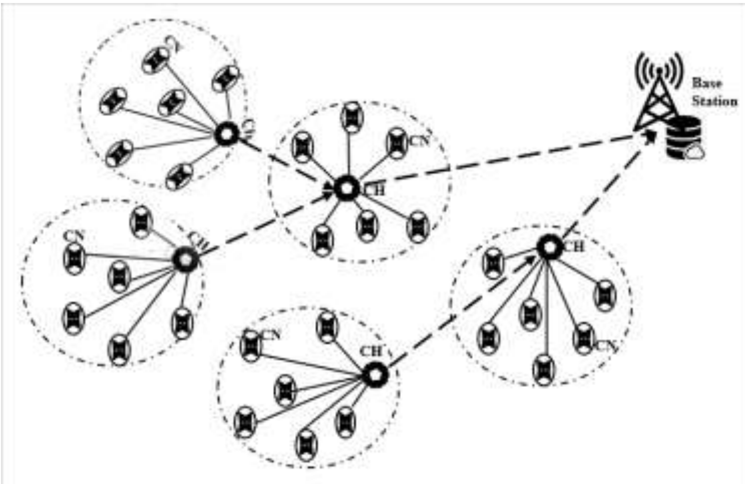

Fig. 1. Multihop Cluster Head Communication to Base Station

2. Literature survey

Keeping in view the energy utilization and the performance of the WSNs, Heinzelman et al [9] developed and analyzed an energy efficient cluster-based hierarchical routing algorithm called LEACH. This is an application-specific protocol which works on the principle of clustering. Selection and rotating the duty of a CH for a cluster in a randomized fashion at the beginning of each working round in order to equalize the energy

ISSN- 2394-5125 VOL 7, ISSUE 08, 2020

utilization in the network. As LEACH is a fundamental protocol, various enhancements have been made to the LEACH to cater to the problem of energy efficient clustering : LEACH-E[10], LEACH-D[11], Mod-LEACH[12] , Equitable-LEACH (ELE) [13], PEGASIS[14], HEED [15] and HEEP [16], A-LEACH [17], DEEC[10], PEACH[18], SEP [19].LEACH-C [3] is a centralized based modification of LEACH [9]. Every node forwards its positional information and remaining energy to the BS. Average remaining energy of the network is computed and clusters are formed by using a normalizing approach. HARBP [20] (Hierarchical Adaptive Balanced energy efficient Routing Protocol) proposed use of randomization to equalize energy consumption among the nodes in the network. Probability based selection of a node as a gateway is done in the setup phase proceeding with the election for the cluster head. Non cluster head nodes join to form clusters depending on the minimal communication energy requirements. Collected data of the CHs is transferred to BS or a gateway node depending on the less energy requirements for transmission. Younis et al proposed HEED [15], which uses remaining energy of nodes in a cluster and the AMRP cost function for periodic selection of CHs. Direct or multi hop transmission is used to communicate data from the CHs to the BS depending on the distance between the two. A chain-based communication protocol employs a greedy approach of chain forming among the nodes. A communication chain is formed and each node is able to talk to its closet neighbor, in a chain or cyclic way. Predefined information of the network topology is required for PEGASIS [14] thus rendering this approach less useful in network of mobile nodes. Marjan et al [21] proposed the application of heuristic algorithm-Basic GSA, for the finding of a best fit for a BS in a 2 tier heterogenous WSN. In a heterogenous setup each node may have a unique date with unique transmitting energy requirement or any other. The higher the value of fitness the longer the lifetime of the network and therefore the corresponding BS location is better. An extension of LEACH named as Energy Efficient Clustering Protocol (EECP) was proposed by Surender et al [22] EECP was developed for a single hop heterogenous WSN spread out uniformly. Gateway nodes (resource rich nodes) were utilized to transfer the data to the base station if selected as a CH in the setup phase. A non-gateway node CH is selected by calculating the distance from the BS and all other non-CH gateway nodes. The non-gateway node CH collects and transfers the data to the nearest gateway node which in turn transfers it to the BS. With the decrease in the communication distance less energy was required, therefore increasing the lifetime of the network. An approach to reduce intra-cluster communication overhead, Buddha et al [23] proposed the use of Particle Swarm Optimization (PSO) to choose a node as CH that is at optimal location in a cluster. It was called Particle Swarm Optimization -Semi Distributed (PSO-SD) as it only focused on intra-cluster management rather than BSs. A fitness function for the right choice of a CH is calculated on following parameters: remaining energy, distance between the clusters, node degree and count for a node of being a CH. A cluster assistant node is randomly chosen in a cluster which has only task of performing computations for PSO and containing information about the parameters. This approach maximized the lifetime of a network and outperformed other existing techniques like PSO-C and LEACH. This protocol was limited to a uniform distribution of nodes in a circular region and the location of BS was fixed at the centre. An attempt to apply fuzzy based multiple attribute decision making (MADM) techniques by Azad et al[24] to prolong the survival of a WSN by the selection of most favorable CHs. While choosing a CH Three characteristics like remaining energy, number of adjacent nodes and the aloofness of base station from the nodes. A node connects with a CH with lesser distance (Euclidean Distance) to the BS. If the CH is far from the node, as compared to the BS, the node directly communicates with the BS using the fuzzy TOPSIS technique. Eventually with the death of nodes, smaller clusters merge with the bigger ones thus balancing energy utilization and increasing the lifespan of a WSN. Simulation results show that this methodology achieved a good energy management as compared to existing distributed hierarchical agglomerative clustering (DHAC) but only in homogeneous setup of nodes. To attend to Sepehr et al [25] proposed a dynamic and user independent method for the calculation of number of desirable clusters and cluster heads based on the energy usage and the communication link, organization of clusters (depending on energy levels) and finding out the best candidate for CHs in each operation cycle. The proposed modified GSA (PDSS-GSA) was developed with power distance sums scaling method (equation) for calculation of mass. With use of fuzzy logic controller, the parameter α acts as controller for the scaling function and thus balances the productive and exploratory nature of GSA. As stated in the proposition: greater the value for α, more the mass of an agent, therefore better solution for the head of a cluster by the algorithm. The lesser the mass of the agent, search for the best solution continues till a solution is found. All the computations were done at the BS. CEC test functions and Freidman's non parametric statistical test was employed to analyze the performance of PDSS-GSA for the GPS enabled stationary sensor network against other WSN energy aware clustering algorithms like LEACH, LEACH-C and PSO-C.In a multipath routing environment, achieving a trade-off between increased lifetime of a network and the transmission response time, Faouzi et al[26] proposed a power efficient and adaptive latency hierarchical cluster-based protocol named as PEAL. The cluster head selection was done on the basis of residual energy of each node. The network was divided into two zones near and far. If a cluster head falls in the near zone, it transmitted the data directly to the base station where as cluster head falling into far zone, appropriate nearest neighbor cluster head was used to forward the data. By this the protocol minimized the response time and increased the lifetime of a network. In [27] an attempt to employ firefly technique to solve the WSN clustering problem was made. A synchronous firefly algorithm was proposed by taking the following features in consideration: ranking of fireflies based on their reproduction capability and selecting the fireflies with best genes among the top ranked set of fireflies. After the calculation of these values' optimal solutions for cluster formation and cluster head selection were achieved.

Preliminaries

This part of the paper defines the abbreviations, Energy/Radio Model, network model and description of Gravitational Search Algorithm (GSA).

- **Notations**

The notations and abbreviations used in this study are shown in Table 1:

Table 1. Description of Notations Used

Notation	Description
E_{Tx}	Energy utilization for transmission
E_{Rx}	Energy utilization for reception
E_{amp}	Energy utilization for amplification
E_{DA}	Aggregated energy
E_{fs}	Energy utilization for free space model
E_{mp}	Energy utilization for multi-path fading channel model
$M_{a,j}$	Active gravitational mass of j^{th} particle
$M_{p,i}$	Passive gravitational mass of i^{th} particle
f_{ij}	Force between agent i and j
m	Denotes number of associate members in a CH
i	Denotes number of sensor nodes
$k_{optimal}$	Denotes optimal number of CHs
m_{ii}	Inertial mass of i^{th} agent
$R_{i,j}$	Euclidean distance between agent i and j
T	Maximum number of iterations
E_{elec}	Energy consumed in transmitter circuitry
r	Random number between 0 and 1
prob	Represents the election probability
d_{bs}	Distance from the base station

First-order radio model proposed in [3][9] for the radio hardware energy consumption where the transmitter dissipates power to run the radio electronics/circuitry (E_{elec}) and the power amplifier

$(E_{fs}d^2(free\ space\ \ power\ loss), E_{amp}d^4(multipath\ power\ loss)$.

Thus, to transfer one-bit message over a distance, the radio expends:

$$E_{Tx}\,(l,d) = E_{Tx-elec}\,(l) + E_{Tx-amp}\,(l,d) \qquad \mathbf{(3.1)}$$

$$= \begin{cases} l * E_{elec} + l *\ E_{fs} * d^2,\ if\ d <\ d_o \\ l * E_{elec} + l * E_{amp} * d^4,\ if\ d \geq\ d_o \end{cases} \qquad (\mathbf{3.2})$$

and for receiving the message, the radio expends as given in below Eq. 3.3

$$E_{Rx}\,(l) = E_{Rx-elec}\,(l) = lE_{elec} \qquad \mathbf{(3.3)}$$

- **Network Model:**

A two tired WSN architecture has been deployed for Apple Crop monitoring and is assumed with the following features. The sensor nodes are immobile and random distribution is followed. The base station is located outside the sensing field. Four different type of sensors are used to monitor the crop leaf wetness sensor, temperature sensor, humidity sensor and soil moisture sensor. Each cluster consists each of the four type of sensors and communicate the collected data to the base station through their respective chosen cluster heads by our proposed algorithms.

- **Overview of GSA**

A recent meta-heuristic optimization technique devised by E. Rashedi et al. [7]in 2009 with the aim to find optimal solutions to the NP Hard problems. This optimization algorithm has its base on the principle of Newtons law of gravity and motion: “Each particle in the universe attracts every other particle with a force called as Gravitational Force which is directly proportional to the product of their masses and inversely proportional to the square of distance between them (R)”.

GSA can be viewed as an artificial isolated system of masses conforming to the gravitational laws. In GSA agents are referred to as objects and the performance is a measure of their masses. Each of the object attracts one another by the gravity force and therefore a global shifting of lighter masses towards the heavier masses occurs. These agents with higher masses prove to good solutions. Each agent has four characteristics: position, inertial mass, active gravitational mass and a passive gravitational mass. Each agents position provides a solution but the optimal solution is obtained with the adjustments in the parameters of gravitational and inertial mass of a fitness function.

$$X_i = \left(x_i^1, \dots \dots x_i^d, \dots \dots x_i^n\right) \;\; for\; i = 1,2,3, \dots \dots, N, \qquad \textbf{(3.4)}$$

where x_i^d stands for the position of an i^{th} agent in the d^{th} dimension.

The force acting on mass *“i”* from mass *“j”* at time *“t”* is defined as:

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t) + \in}\left(x_j^d(t) - x_i^d(t)\right), \qquad \textbf{(3.5)}$$

where M_{pi} is the measure of strength of an agent’s interaction with the gravitational field is called as passive gravitational mass (PGM).PGM is directly proportional to the force experienced by the object and M_{aj} is the measure of strength of the gravitational field due to a particular agent referred to as active gravitational mass of agent *j*. More the active gravitational mass of an object stronger is the gravitational force and vice versa.

G(t) is gravitational constant at time *t*, ∈ is a small constant, and $R_{ij}(t)$ is the Euclidian distance between two agents *i* and *j*.

Table 2: Critical limits taken in account each sensor

Type of sensor	Critical limit range
Rain sensor	**>0.09mm &<=12mm**
Humidity sensor	**>79.99% & <=120%**
Temperature sensor	**>11.490c & <=380c**

By the law of motion, the acceleration of the agent *i* at time *t* and in d^{th} direction is given by

$$a_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \qquad \textbf{(3.6)}$$

where M_{ii} is the inertial mass of the i^{th} agent.

After generation of acceleration, the next velocity and position of an agent is updated using following equations respectively:

$$v_i^d(t+1) = rand_i \times v_i^d(t) + a_i^d(t), \qquad \textbf{(3.7)}$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1), \qquad (3.8)$$

where $rand_i$ is a uniform random variable in the interval [0,1], x_i^d is the velocity and x_i^d is the position. $v_i^d(t)$and $x_i^d(t)$ is the current velocity and position of an agent at time t.

Mapping function are used to calculate the mass from the fitness values (a heavy mass means an optimal solution) as given below:

$$M_{ai} = M_{pi} = M_{ii} = M_i,\ i = 1,2,3, \ldots \ldots, N, \qquad (3.9)$$

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \qquad (3.10)$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \qquad (3.11)$$

where $fit_i(t)$is the fitness value for agent i at time t, $best(t)$,$worst(t)$ can be either minimization and maximization values.

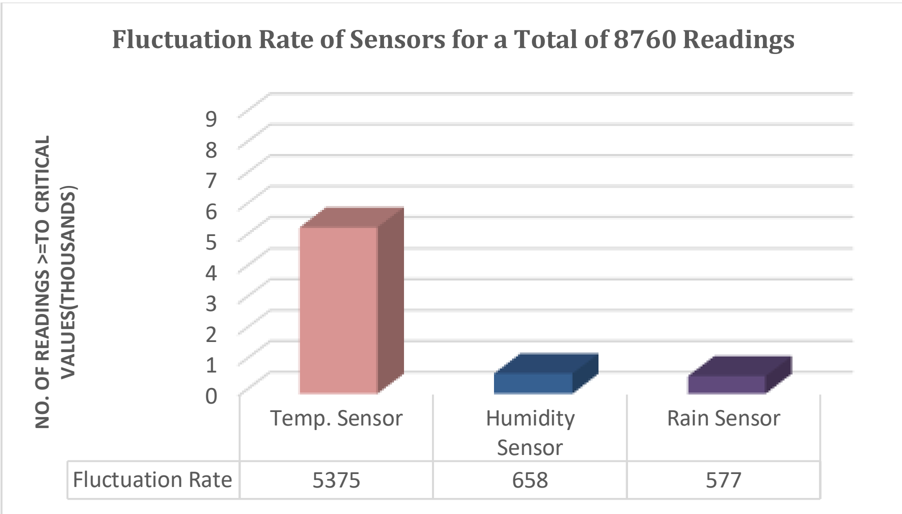

Fig.2. Fluctuation Rate of Sensors Based on Analysis of Previous Data from SKAUST-K

3. The Proposed Model

In this we propose a novel clustering, data collection and data transmission algorithm for wireless sensor network for monitoring of apple crop orchard parameters. The proposed algorithm is named as Parameter Aware Sensing Clustering Protocol (PASC) The working of the divided into three phases: the cluster head selection phase, cluster formation phase and data transmission phase. Each sensor knows when each round starts using a synchronized clock as proposed in [3]. The next subsections explain all the three phases.

Setup Phase

In this phase each node examines its quality to become a cluster head (CH) based on the following criteria: fluctuation rate, probability of becoming a CH, head-set, remaining energy and optimal number of clusters. Dynamic cluster formation is followed and CH's are elected randomly and all nodes are assumed to have same energy levels.

- **Cluster head election phase**

The consideration taken for highest, lowest and critical values for temperature, leaf wetness, rain and humidity sensor for the apple scab disease prediction and growth are accordingly as defined in Mills Table[28]and pathological experts of SKAUST-K. The fluctuation rate is computed as:

$$f\_rate = \frac{count}{R} \qquad (4.1)$$

ISSN- 2394-5125 VOL 7, ISSUE 08, 2020

where R is the total number of reading and $count$ is the number of reading that are above the critical levels.In our case it was found that rain moisture had not much impact on the disease growth and had less data values to forward which had least variations thus less fluctuation rate, among all other four type of sensors. The data values from other sensors like LW, Humidity, Temperature have far reaching effects on the development of Scab infection, therefore their fluctuation rate is also high as compared to rain moisture sensor. For the Scab prediction of Apple crop, leaf wetness plays the most important role in the growth and spread of Scab infection, therefore it needs to be monitored closely and cumulatively. So, for leaf wetness sensor, fluctuation rate is taken as 1. On the analysis of previous dataset with 8760 reading for each sensor type, collected by SKAUST-K (Sher-i-Kashmir Agricultural University of Science and Technology-Kashmir, India: for temperature the fluctuation rate was computed as 0.3618, for humidity sensor it is taken as 0.1438 and for rain sensor it is taken as 0.0860 with taking the following critical limits in account as shown in Table 2.

If any parameter is fluctuating more, then it means that type of sensors will have to send more data and they will be consuming more energy, their probability of becoming cluster head will be reduced that is defined as:

$$prob(i) = \frac{1}{f\_rate(i)} \qquad \textbf{(4.2)}$$

where $f\_rate(i)$ is the fluctuating rate for a particular parameter. The order of probability for cluster head selection and fluctuation rate for our case is as: RS>Hum>Temp.>LW as shown in Fig.2.

The nodes with low fluctuation rate have high chances to be chosen as the CH, which drifts away the balance of the energy dissipation of the network. In order to balance the CH selection and cater to the problem of energy drain of a particular sensor node having less fluctuation rate and high probability of becoming a CH, with respect to other nodes the selection will be governed by threshold value, $threshold\ (i)$ based on the amount of its remaining energy:

$$threshold\ (i) = \begin{cases} \frac{prob(i)}{1-prob(1)\{r(mod\frac{1}{prob(i)})\}} * \frac{\varepsilon_i}{\varepsilon_o}\ ;\ for\ all\ i \in G \\ 0;\ Otherwise \end{cases} \qquad \textbf{(4.3)}$$

$$\mathcal{E}_i = Remaining\ Energy\ of\ node;$$

$$\mathcal{E}_o = in\ tial\ energy, r\ is\ round\ number$$

The selected candidate CH's broadcast advertisement (ADV) packets to all non-CH nodes in their communication range. Depending on the communication ranges a node chooses its nearest CH. The decision of the nodes is transmitted to the CH and so that it remembers its neighbour nodes. The responsible CH selects a set of m associates (head-set) for every cluster, based on the signal as:

- **Cluster Formation phase**

At each start the remaining energy of nodes is verified and only those with high battery are listed as the suitable active CH candidates. By the end of this phase head-sets (group of nodes as associates) from the list of candidate CH's are formed based on signal analysis. In this phase each node (i) generates a random number r between the 0 and 1, and compares it with threshold value, $threshold\ (i)$. If the threshold value is greater than the random number, node becomes eligible to be the CH else it will remain as cluster member. The threshold value as defined is given as [3] is modified as:

$$threshold\ (i) = \begin{cases} \frac{prob(i)}{1-prob(1)r\left(mod\frac{1}{prob(i)}\right)} * k_{optimal} * \frac{\varepsilon_i}{\varepsilon_o}\ ; \\ 0;\ Otherwise \end{cases}$$

$$for\ all\ i \in G \qquad \textbf{(4.4)}$$

where $k_{optimal}$ [29] is the optimal number of clusters to be formed for (i) nodes.

$$k_{optimal} = \sqrt{\frac{n}{2\pi}}\sqrt{\frac{\mathcal{E}_{fs}}{\varepsilon_{mp}*d^4\ (2m-1)\varepsilon_o - m\mathcal{E}_{da}}} * M \qquad \textbf{(4.5)}$$

'M' represents the network diameter, $\mathcal{E}_{fs}$ is for the free-space model, ε_{mp} is the multipath model, $\mathcal{E}_{da}$ is energy consumed for data aggregation, d is distance to the receiver and m=3.

The energy level among the head-set associates, m is uniform. The phase ends with only one member of the head-set is active state that is as a CH and the remaining are in the associate state denoted as m. The active CH perform the duty of sending data to the base station and this duty is apportioned within the head-set members until the energy level are not dying.

Steady State Phase

In this phase, each cluster head sends Time Division Multiple Access (TDMA) schedule to the nodes for data transmission. Every cluster member sends the sensed data to the respective cluster head. The cluster heads

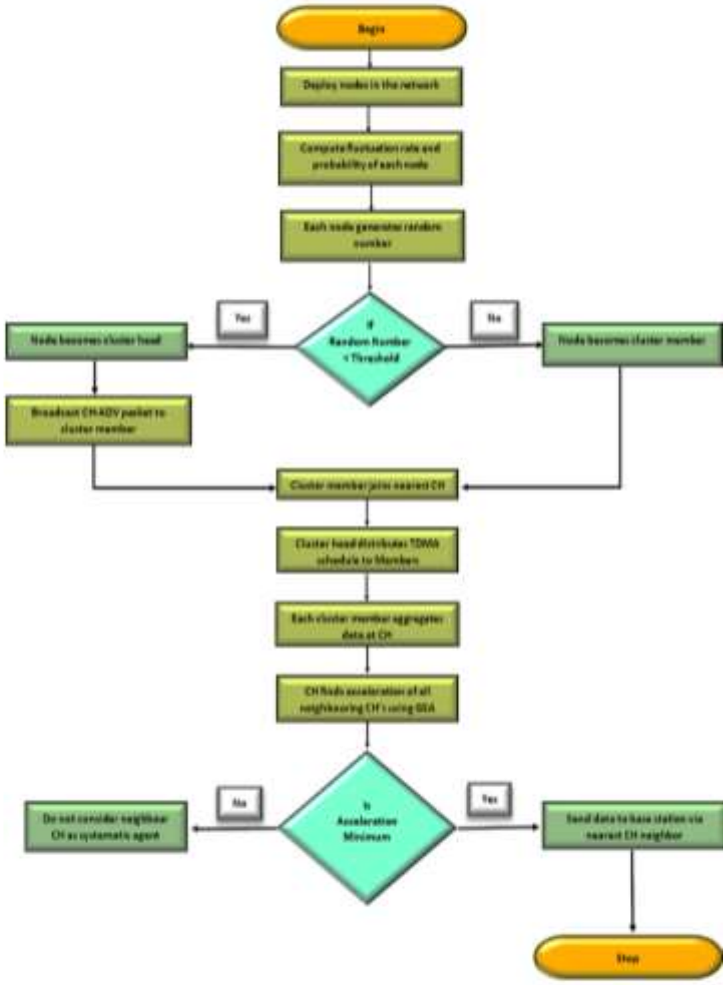

Fig.3: Working flowchart of Parameter Aware Sensing and Clustering Protocol

make use of multi hop communication to send aggregated data to the base station. The next hop cluster head is selected by applying the gravitational search optimization technique.

- **GSA- Based Data transmission phase**

To select the next hop optimal path from every CH to the BS using distance of the cluster head from the base station, remaining energy of the node and cluster size is formulated in this phase. The fitness function of each cluster head(agent) is computed using the above three parameters as following:

$$fitness(i) = w_1 * d_{bs} + (1 - w_2) * \mathcal{E}(i) + w_3 * size\ of\ cluster \quad \textbf{(4.6)}$$

d_{bs} is distance from base station, $w_1, w_2, w_3 = 0.33$ are the weighted values (weighted sum approach).

The gravitational mass $G.M.(i)$ of each agent (node) is calculated as:

Table 3: Algorithm for the Optimal Cluster Head Selection

Inputs:	(1) Set of sensor nodes $i = (i_1, i_2, i_3, \ldots i_n)$
	(2) Compute fluctuation rate
	(3) Compare threshold value
	(4) Elect cluster head
Results:	Set of eligible cluster heads

Step 1: Suppose N: Total number of nodes

Step 2:

for *i = 1:N*

Compute *fluctuation rate* ***Using Eq. 4.1***

Compute *probability* ***Using Eq. 4.2***

End for

Step 3:

f_rate ()

count=0

for *i=1:R*

if *reading(i) > Critical value parameter*

count++

end if

end for

Step 4:

for *i=1:N*

Node(i)

Compute Threshold (i) *Using* ***Eq. 4.4***

if *Random no.(i) < Threshold (i)*

Node becomes cluster head

Else

Node becomes cluster member

End if

End for

Step 5: Each cluster head broadcasts ADV to nodes in its communication range.

Step 6: Each node joins nearest cluster head by sending cluster head join (CH Join) packet.

Step 7: Each cluster head distributes TDMA to its cluster member.

Table 4: Algorithm for GSA- Based Routing

Inputs: (1) Set of CH nodes

(2) Compute fitness

(3) Compare distance and communication range

(4) Find acceleration

Results: Next hop optimal routing path

Step 1: Suppose CH is the set of cluster heads

Step 2:

for *i= 1:CH*

find fitness ⊳ *Using* ***Eq. 4.6***

end for

Step 3:

for *i=1:CH*

for *j=1:CH*

if *Dist (CH_i, CH_j) < Communication Range*

find minimum fitness(i)

find maximum fitness(j)

end if

end for

worst=max{fitness(j)}

best = min{fitness (j)}

end for

Step 4:

for *i=1:CH*

4.1 Find Gravitational Mass ⊳ *Using* ***Eq. 4.7***

4.2 Find Inertial Mass ⊳ *Using* ***Eq. 4.9***

4.3 Find gravitational force between CH(i) and its neighbour ⊳ *Using* ***Eq. 4.8***

4.4 Find acceleration ⊳ *Using* ***Eq. 4.10***

4.5 Choose agent (neighbouring CH) with minimum acceleration

to forward data to Base Station.

End for

Step 5: Each member forwards data to CH.

Step 6: CH forwards data to Base Station via chosen agent

$$G.M.(i) = \frac{fitness(i) - worst}{best - worst} \qquad (\mathbf{4.7})$$

where $worst = max\,\{fitness(j)\}$ and $best = min\,\{fitness(j)\}$

The agent with higher $G.M.$ prove to be good solutions for the next hop CH selection. The amount of force that acts between the source CH $I.M.(i)$ and the destination or the neighbouring CH $I.M.(j)$ has been calculated by modifying **Eq. 3.5**:

$$G.Force = G.Const * \frac{I.M.(i) * I.M.(j)}{Distance}\,(X_i - X_j) \qquad (\mathbf{4.8})$$

where $I.M.(i)$ is the inertial mass of the object given by:

$$I.M.(i) = \frac{G.M.(i)}{\sum_{j=1}^{n} G.M.(j)}\,; \qquad (\mathbf{4.9})$$

$$where\ n\ is\ the\ no.of\ neighbouring\ CH's.$$

Table 5: Simulation Parameters

Parameter	Value
Network diameter	100 x 100 m2
Base Station Location	(50,175)
Total number of nodes	100 nodes
Initial energy (E_0)	2 J
Energy dissipation: receiving (E_{elec})	50 nJ/bit
Energy dissipation: free space model (E_{fs})	10 pJ/bit/m^2
Energy dissipation: power amplifier (E_{amp})	0.0013 pJ/bit/m^2
Energy dissipation: aggregation (E_{DA})	5 nJ/bit

The cluster head chooses the next hop cluster head with minimum acceleration to send data to the base station that is computed as:

$$Acc = \frac{G.Force}{I.M.(i)} \qquad (\mathbf{4.10})$$

Each member forwards data to CH and the CH forwards the data to the base station via the chosen agent with the help of GSA. A flowchart for PASC is shown in Fig.3.

Pseudo code for the proposed protocol

The pseudocode for the proposed PASC protocol is discussed Table 3 for Optimal Cluster Head Selection and Table 4 for GSA based routing phase respectively.

Simulation Setup

The performance of our proposed protocol PASC is evaluated using the Network Simulator (NS2.34). The inputs for the experimental run consist of 100 nodes with random distribution on an area of 100 x 100 m^2. We assume all the nodes are stationary throughout the simulation time. Fig. 4 shows the network topology and the node deployment. The simulation parameters are summarized in Table 3.

- **Simulation Results**

The performance evaluation of the proposed algorithm PASC with other existent algorithms have been compared on the basis of remaining energy, total live nodes and network lifetime.

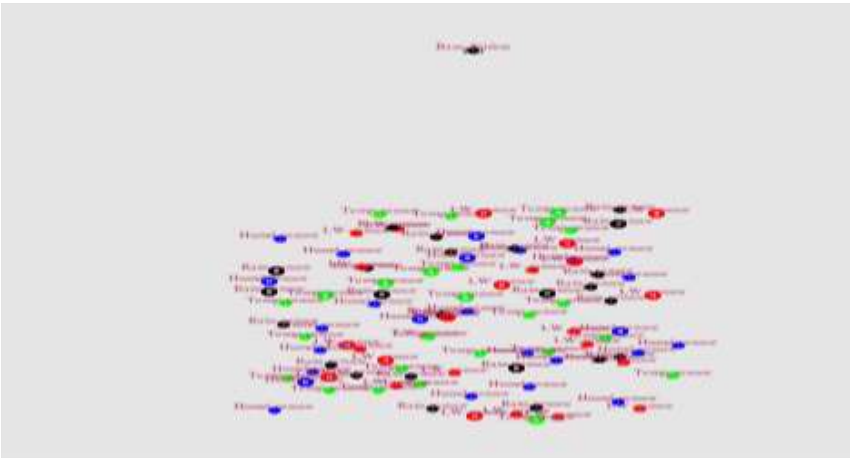

Fig. 4: Network Deployment on 100 x 100 m^2 Area

- **Remaining Energy**

Each sensor node utilizes its battery power in transmitting, receiving and aggregating the information. After such process are completed, the remaining (leftover) energy, if present in good amount can enhance the performance of the network. The proposed approach PASC helps the network from draining out of the power and dissipates all the energy of the

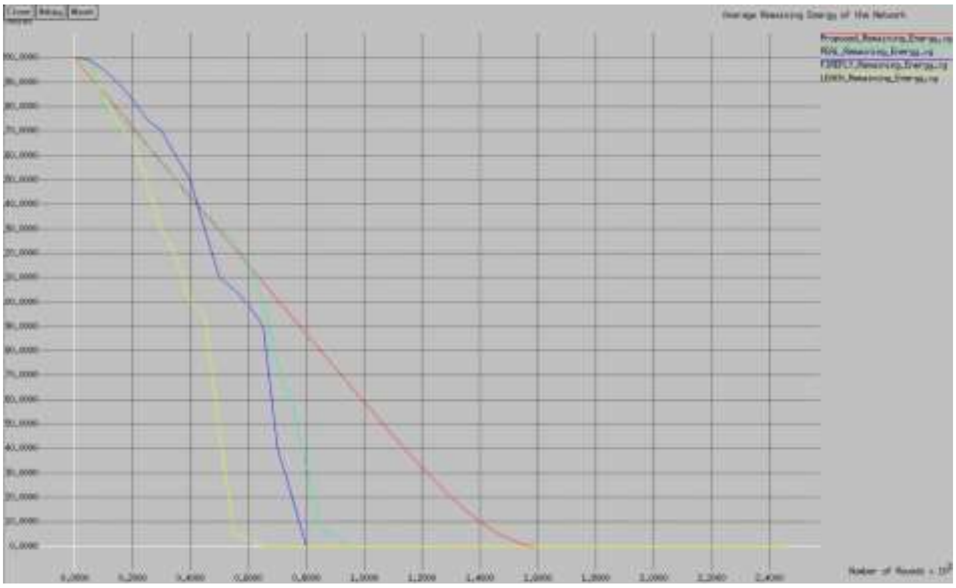

Fig.5. Energy consumption of proposed algorithm w.r.t. remaining energy

network after 1550s, whereas the comparative protocols like LEACH[9], PEAL [26] and FIREFLY[27] drained out the network after 650s and 950s respectively as shown in Fig.5.

- **Number of Alive Nodes**

The second evaluation metric is to examine the proposed algorithm in terms of the number of nodes alive in comparison to LEACH and PEAL. The simulation results in Fig.6 showed quick death of nodes in comparative protocols while slow in PASC. The first node died at 950s thus doubles

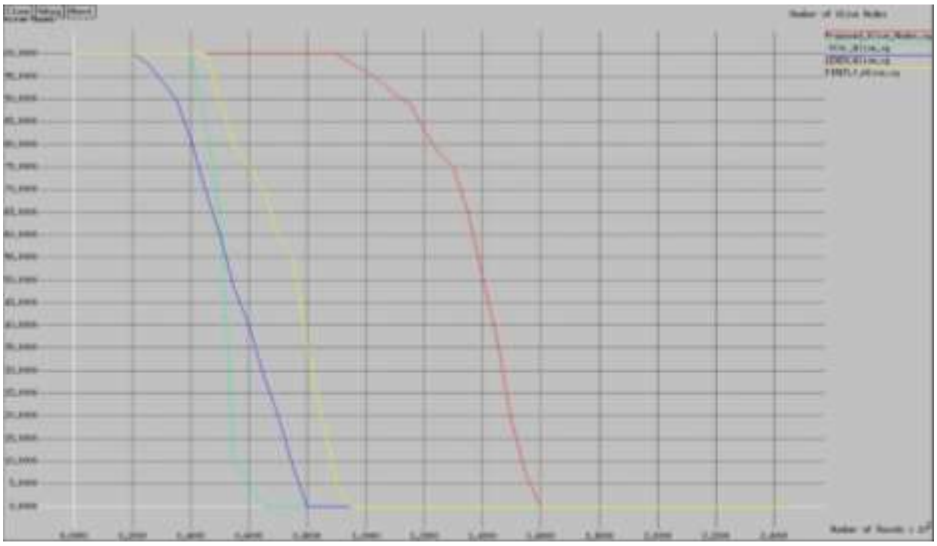

Fig.6. Results for number of alive nodes over simulation time

the delaying of death of first node as compared to FIREFLY, PEAL and LEACH.

- **Network Lifetime**

With the increase in lifetime of a network the performance also enhances. In this study, first node death has been perceived for network lifetime as shown in Fig.7. The selection of a sensor node as a CH and next hop node with high remaining energy, reduces the chances of rapid death of the CH, hence increasing the lifetime of the network.

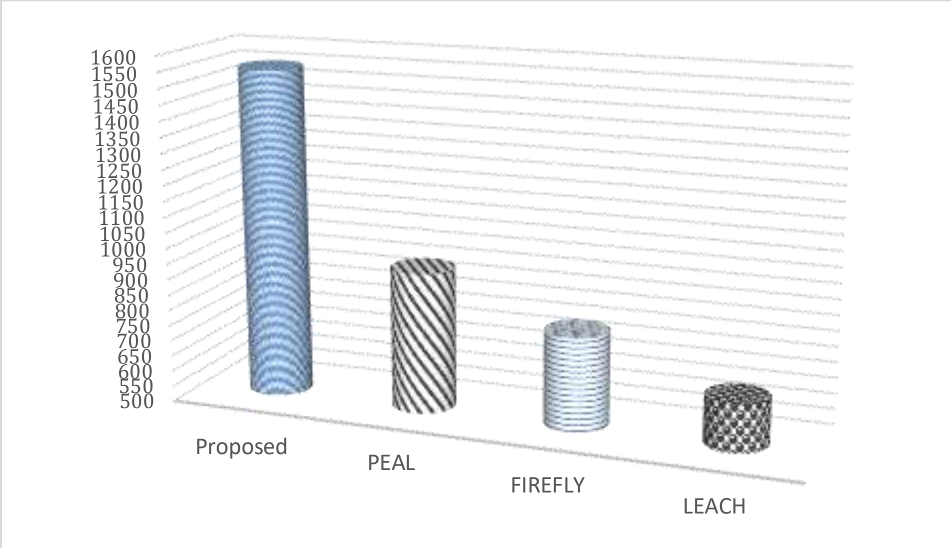

Fig.7: Comparison of Network Lifetime

4. Conclusion

The role of WSN in providing real time data about critical parameters through spatially deployed sensors, for monitoring of Apple crop is very significant. Depending on the values of each parameter measured using sensors, accurate and reliable advisory can be developed to predict onset of diseases, therefore helping the farmers of Kashmir Valley to save the crop loss and overdose of chemical sprays. In this study an attempt has been made to demonstrate the efficiency of GSA in solving application specific optimization problems related to WSN routing. A novel approach of using application specific parameter sensing (apple crop), CH selection and optimized GSA based next hop node selection was developed to cope up to the challenge of power consumption and increase in lifetime of a WSN deployment. The Critical limit of any parameter can be set according to the requirement of the crop, thus boosting the inclusion of WSN in agricultural crop monitoring and a step towards smart farming.

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