This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

Particle Swarm Optimization based Clustering by Preventing Residual Nodes in Wireless Sensor Networks

Rejina Parvin , *Assistant Professor*, Vasanthanayaki C, *Associate Professor*

***Abstract*— Particle Swarm Optimization based effective clustering in Wireless Sensor Networks is proposed. In the existing OEERP, during cluster formation some of the nodes are left out without being a member of any of the cluster which results in residual node formation. Such residual or individual nodes forward the sensed data either directly to the Base Station or by finding the next best hop by sending many control messages hence reduces the network lifetime. The proposed E-OEERP reduces/eliminates such individual node formation and improves the overall network lifetime when compared to the existing protocols. It can be achieved by applying the concepts of Particle Swarm Optimization (PSO) and Gravitational Search Algorithm (GSA) for cluster formation and routing respectively. For each Cluster Head, a supportive node called Cluster Assistant (CA) node is elected to reduce the overhead of the Cluster Head. With the help of PSO, clustering is performed until all the nodes become a member of any of the cluster. This eliminates the individual node formation which results in comparatively better network lifetime. With the concept of GSA, the term force between the cluster heads is considered for finding the next best hop during route construction phase. The performance of the proposed work in terms of Energy Consumption, Throughput, Packet Delivery Ratio and Network Lifetime are evaluated and compared with the existing OEERP, LEACH, DRINA, BCDCP protocols. The work is simulated using NS-2 simulator. The results prove that, the proposed E-OEERP shows better performance in terms of lifetime.**

***Index Terms*— Cluster Formation, Gravitational Search Algorithm, Particle Swarm Optimization, Routing**

I. Introduction

IN RECENT years, Wireless Sensor Network (WSN) has drawn many research works predominantly due to its plenty of applications in various fields. This includes Environmental Monitoring, Health Monitoring, Military Tracking [1], Animal Tracking and Monitoring [2]. WSN refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of an environment and organizing the collected data at a central location through wireless links [3]. The physical conditions may include pressure, temperature, soil moisture, etc. Each sensor node in Wireless Sensor Network is equipped with a radio transceiver, a microcontroller, an interfacing electronic circuit and an energy source, usually a battery [4].

Manuscript received June 09, 2014; revised March 11, 2015; accepted March 16, 2015, Non-Funded Project. The associate editor coordinating the review of this paper and approving it for publication was Prof. Kiseon Kim.

J. Rejina Parvin, Assistant Professor, Dept. of Electronics and Communication Engineering, Dr. N.G.P Institute of Technology, Coimbatore, Tamil Nadu, India. (e-mail: parvinece@gmail.com).

C. Vasanthanayaki, Associate Professor, Dept. of Electronics and Communication Engineering, Govt. College of Technology, Coimbatore, Tamil Nadu, India. (e-mail: vasanthi@gct.ac.in).

The energy source in WSN should be handled in an efficient way as it cannot be replaced or recharged if it is placed in harsh or no man environment [5].

Transmitting the sensed data to the Base Station can be done using various methods which includes: Single-hop transmission, Multi-Hop transmission, Cluster based transmission, Tree based and Chain based transmissions [6].

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first cluster based hierarchical routing protocol. In this protocol, each node in the cluster has a chance to become a Cluster Head [7]. Many other clustering and routing algorithms are available for efficient data gathering and transmission [8]. Clustering method of data aggregation and transmission results in better lifetime as it eliminates the data redundancies [3]. Generally in clustering networks, sensor nodes are grouped into various clusters and each cluster has a Cluster-Head (CH). All cluster nodes transmit the sensed data to its respective CH. CHs aggregate the cluster node's data and the aggregated data is directed to the sink node.

During cluster formation, it is not sure that all the nodes are becoming a member of any of the cluster. There may be some left-out nodes also in the sensing region after cluster formation which is generally called as individual nodes [6]. Such nodes require higher energy for transmitting the sensed data directly to the sink node. Else such nodes need to send many control messages to find the next best hop for constructing the optimal routing path. Optimized Energy Efficient Routing Protocol (OEERP) provides better network lifetime [6]. While clustering using OEERP, some nodes are left out in the network without being a member of any of the cluster in time t_1. After sometime, the same individual nodes may become member of any cluster in the network and some other nodes may become left out nodes during next cluster formation. The same process is repeated in every cluster formation. In the proposed work, Particle Swarm Optimization (PSO) algorithm is used for cluster formation and Cluster Head election. Care is taken to avoid such individual node formation during clustering. Here Average Clustering Ratio is computed to avoid the residual node formation.

Another major factor that affects the network lifetime is routing path construction. The constructed path should be highly reliable. In the proposed system, the concept of Gravitational Search Algorithm (GSA) is used to find the next best hop. Parameters like position of the node, velocity and force between the cluster heads are considered for selecting next best hop. The clusters with maximum force are selected to forward the aggregated data from cluster head until it reaches the Base Station.

The rest of the paper is organized as follows. Related works and the experimental set up of the proposed system are explained in Section 2 and 3 respectively. Proposed work is compared with the existing routing protocols and discussed in Section 4. Conclusion and scope for future work is given Section 5.

II. RELATED WORKS

Many research works are concentrated on efficient clustering, data gathering, aggregation and routing techniques. Some of the major existing cluster based routing protocols are discussed below.

A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is a self-organizing clustering protocol. This includes rotation or random election of Cluster-Head. The CH election is based on the node with higher-energy and accessibility [9]. The elected CHs perform data fusion for data compression. This improves the overall network lifetime, as the compressed data is only being transmitted to the sink node. Various phases of LEACH protocol are,

1. Advertisement Phase

Each node chooses a random number between 0 and 1. If the chosen number is less than a threshold value *T(n)*, the corresponding node becomes Cluster-Head (CH) for that particular round.

$$T(n) = \begin{cases} p/\{1-p\,(r \bmod (1/p))\} & \text{if } n \in G \\ 0 & \text{else} \end{cases} \qquad (1)$$

Threshold value can be calculated using Eq.1. where,

n - number of nodes

p - desired percentage of a node to become a CH

r - current round

nodes which has not become as CH in the past 1/p rounds which is represented as G [4].

CHs then advertise the election by broadcasting an "*Adv_ message*" [10].

2. Cluster Set-up Phase

Sensor nodes inform the respective CH about its decision to join with it as cluster nodes. It is performed using Carrier Sense Multiple Access (CSMA) MAC protocol. The same procedure is followed for the entire cluster formation.

3. Steady State Phase

CHs create a TDMA schedule for transmitting the sensed data for each of its cluster member. This makes the nodes to transmit the sensed data in the allotted time slot. Once CH receives cluster nodes data, it performs data aggregation and the result is communicated to the sink node. The energy dissipation of each node is minimized by *turning off* its radio until its transmission time [4].

LEACH does not require global knowledge of the network as it may further reduces its energy dissipation.

B. BCDC Protocol

Base-station Controlled Dynamic Clustering Protocol (BCDCP) is a centralized routing protocol [11] with base station as an essential component with high computational abilities. The various phases of BCDCP are [11]:

1. Set-up Phase

This phase includes,

a. Cluster Head election

b. Cluster Formation

c. CH-CH routing path information

d. Schedule creation for cluster

Once the base station receives the energy level of all the sensor nodes, cluster splitting algorithm is used to perform cluster formation and Cluster Head election. It splits the entire network into two sub-clusters, then into smaller clusters until required number of clusters is attained. CHs are placed at maximum distance in order to provide uniform coverage throughout the field [11].

Average energy value is calculated and a threshold value is fixed. Nodes with sufficient energy are elected as CHs for that particular round [11].

This protocol uses CH to CH multi-hop routing scheme which identifies the lowest energy routing path. Cluster formation and CH information are forwarded through this route. Routing paths are selected using the minimum spanning tree approach.

2. Data Communication Phase

This phase involves,

a. Data Gathering

b. Data Fusion

c. Data Routing

Base station assigns a Schedule Criterion ID (SCID) for all the nodes with in the cluster. With the help of SCID, all the sensor nodes transmit the sensed data to their respective CH [9]. On receiving the data, CH performs data fusion to prevent collision. It then transmits the fused data to the base station through CH-CH multi-hop routing scheme. This protocol uses Code Division Multiple Access (CDMA) scheme to avoid radio interference produced by neighbouring clusters [11]. Here, cluster formation takes place periodically and the information is being transmitted to the base station. There may be chances for such type of clusters result in the residual node formation in the network.

C. DRINA

Data Routing for In-Network Aggregation (DRINA) [10] is one which performs Routing Tree construction and finding the shortest path that links all the nodes to all other nodes in the network. The following rules are considered for building the routing Tree.

1. Collaborator

Collaborator is generally a node which detects an event and gathers information. The collected information will be transferred to the Coordinator node [12].

2. Coordinator

It is also called as Collaborator node. After the election, it becomes Coordinator node. This node performs Data Aggregation operation and sends the aggregated data to the sink node.

3. Relay Node

The nodes which are in between the Coordinator node and the sink node are called Relay nodes. As these nodes are used to forward the sensed data to the sink node it is said to be relay node.

The major steps of DRINA are [12],

- Constructing the Routing tree
- Electing the Cluster Head (Coordinator)

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

- Forwarding the sensed data to the Base Station

In this protocol, once base station receives the entire node's information, it allows the nodes to form as clusters [12].

D. NEEC

A Novel Energy Efficient Cluster (NEEC) formation is a new clustering method [13]. Here, base station initiates the cluster formation. Identifying the nodes which receives the *maximum_reply* from the node for *request_message* are elected as cluster head [13]. In addition to that, cluster head election takes place based on total energy consumption and co-alive life span. Once the base station receives all the nodes information such as position and the energy level, base station starts performing the cluster formation operation. This may reduce the number of residual node formation as it considers all the nodes during clustering. Node with maximum energy level become as cluster head. And for routing the sensed data, a *route_request* message with a sequence number is sent. With the *reply message* and the sequence, the shortest path is found [13].

E. OEERP

Optimized Energy Efficient Routing Protocol (OEERP) is a cluster-based routing protocol works under the principle that makes uniform battery drain of nodes [6]. The operation of this protocol can be understood with the help of the following phases.

1. Cluster Formation Phase

Cluster Head (CH) election takes place in a random manner. Once the cluster head election is performed, each CH broadcast an *advertisement message* to all the sensor nodes. Nodes which are in the transmission range of a particular CH receive the message. The sensor nodes or cluster nodes then send a reply message with *request message* to join under the particular Cluster Head.

During cluster formation, some nodes may be left out nodes without being a member in any of the cluster in that particular time-slot [6]. But such nodes may become a member of any cluster or even it can become as cluster head of any cluster. So the individual nodes keep on vary from time slot to time slot which results in maintaining the average energy level of all the sensor nodes. But still there are few drawbacks in this protocol which includes,

- Transmitting the sensed information from those individual nodes to sink node is risky as it has to discover the neighbour by sending many control messages which results in high energy consumption.
- If any particular node remains as an individual node for a long period, it may die early.

So, all the nodes have the probability to become a cluster member or CH, thus providing distributed energy dissipation. Once cluster formation is done, the nodes involves in information processing phase.

2. Information processing phase

Each sensor node involves in sensing the attributes depending on the application. The sensed data from each node is transmitted to their respective CH [6]. Once CHs receive the sensed data, it performs data aggregation and this process is repeated periodically.

3. Data Dissemination Phase

Each CH transmits the aggregated data to the base station based on the data dissemination interval [6]. Figure 1 shows the Wireless Sensor Network scenario of OEERP. In that, there are four clusters in the network and each with a Cluster Head. It can be seen that, there are few left out nodes, without being a member of any of the cluster are called residual nodes or individual nodes [6]. But those nodes are capable of sensing and transmitting the sensed data to the base station. Such nodes can sense and transmit the sensed data by finding an optimal path to reach the Base Station.

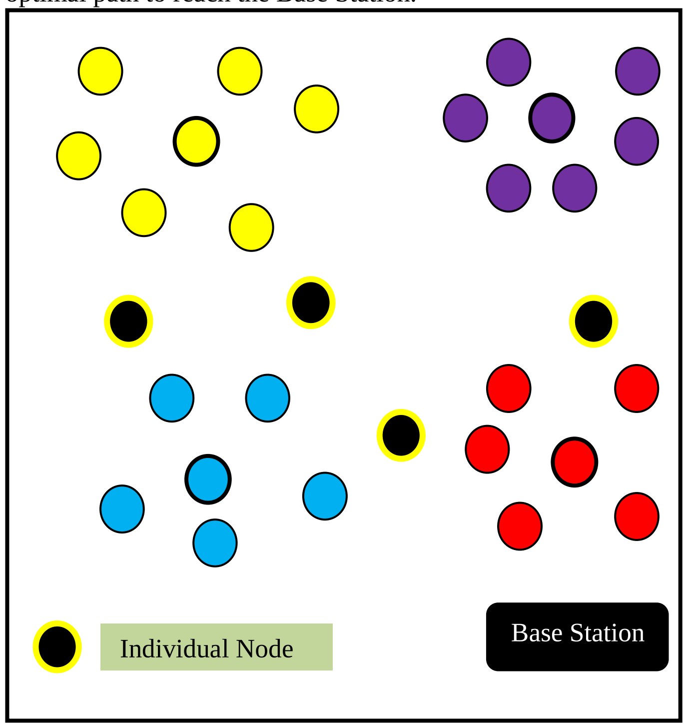

Fig. 1. Cluster formation using OEERP

In this OEERP, even though the individual nodes keep changing from one time slot to other which is an advantage mentioned in [6], there are some drawbacks too. The individual or residual nodes communicate directly to the BS or finding the next best hop by sending many control messages for transmitting the sensed data. This may leads to:

- Data loss
- Early node failure of such individual nodes are higher, as the node consumes more energy by sending many control messages.

So the above mentioned drawbacks are to be overcome in the proposed Enhanced-OEERP (E-OEERP) method.

In this section, major clustering and routing protocols like LEACH, BCDCP, DRINA and OEERP have been discussed. It is observed that, the major limitation of existing clustering protocols is residual node formation which affects the entire network lifetime severely. So the proposed E-OEERP is mainly focused on reducing such residual node formation. The proposed E-OEERP is compared with the OEERP. As the major issue in wireless sensor network is effective handling of sensor nodes, as the nodes have to perform sensing, processing the sensed data and communicate the sensed data to the Base Station. Cluster formation is taken

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

place in order to make the cluster heads to perform data aggregation operation to reduce data redundancies. In the existing OEERP, during each cluster formation, some sensor nodes are left out nodes in each phase. The author of the existing paper suggested that, as all the nodes are somehow will act as an individual node in some duration or in any phase of cluster formation which balances and maintains an average level of energy throughout the network and that may enhances the network lifetime.

III. Proposed PSO based Clustering

In this paper, effective cluster formation takes place using Particle Swarm Optimization in order to reduce the individual/ residual node formation. PSO based energy efficient routing protocol called Enhanced – Optimized Energy Efficient Routing Protocol (E-OEERP) is proposed. Clustering in the existing Optimized Energy Efficient Routing Protocol results in individual node formation [6]. For eliminating such individual nodes, the concepts of Particle Swarm Optimization (PSO) are used for cluster formation. Constructing the optimal routing path to transmit the sensed data is another challenging task in WSN. In the proposed system, Gravitational Search Algorithm (GSA) is also used for constructing an optimal routing path to transmit the sensed data to the base station.

A. Particle Swarm Optimization

Particle Swarm Optimization (PSO) can be referred to as a random optimization technique based on population and was devised by Kennedy and Eberhart in 1995 [14]. They have developed PSO through the inspiration of social behavior of fish schooling or bird flocking. They have demonstrated a solution to a problem of complex non-linear optimization by means of imitating the bird flocks' behavior. Also they have devised the function-optimization concept from a specific swarm.

PSO can be referred as a computational technique that optimizes an issue by using a series of iterations attempting to enhance a candidate solution regarding given quality measure or application. PSO generally optimizes an issue based on candidate population in the search-space in conformity with the mathematical formulae over velocity and position of the particle. In each iteration, *velocity* of each particle is updated using the *current velocity* of the particle and the *previous local_best* and *global_best position* [15-17]. Based on it, *new_velocity*, *new_position* of the particle can be estimated. The same procedure is repeated for each iteration.

PSO encompasses swarm of particles. In general, each and every particle occupies position in the search space. The position's quality is generally being demonstrated by the fitness of each particle which revolves in the search space with a specific velocity. Each particle's velocity is substantially influenced by its best position established in the search space so far and an appropriate solution will be demonstrated by the neighborhood positions. Finally, the swarm will meet the optimal positions [15].

As discussed above, PSO had been devised through the inspiration of social behavior of bird flocking. Consider the scenario in which a flock of birds are arbitrarily seeking food in a locality and there is a single food piece only being searched in the area. No bird knows where the food is available in the area but the birds know how far the piece of food in each series of iterations. Now the key question lies in finding an effective strategy to find the piece of food and the solution is to pursue the bird which is closest to the piece of food [15].

PSO empowered from the above scenario and utilized it to solve the problems of optimization. In the context of PSO, every single solution refers the "bird" in the context of the search space and it could be referred to as "particle". Each and every particle has specific fitness value and is assessed by the aspect of fitness function to be made optimal. And possess velocity which manoeuvres the movement of particles. By means of pursuing the current optimum particles, the particles could fly around the search space [16].

PSO is generally initialized with a random particles' group and in turn explores for optimal solution by means of updating generations [16]. This is shown in Fig. 2. In the context of iterations, every particle is being updated by the maximum values. In which the first maximum value can be referred to as the fitness i.e. the best solution accomplished so far and is known as *pbest*. The second "best" value could be tracked by means of the particle swarm optimizer and is the best value found so far in the whole swarm population and it could be referred to as *gbest* i.e. global best. Likewise, when a particle assumes in the population of swarm as its topological neighbours, it could be known as *lbest* i.e. local best [17].

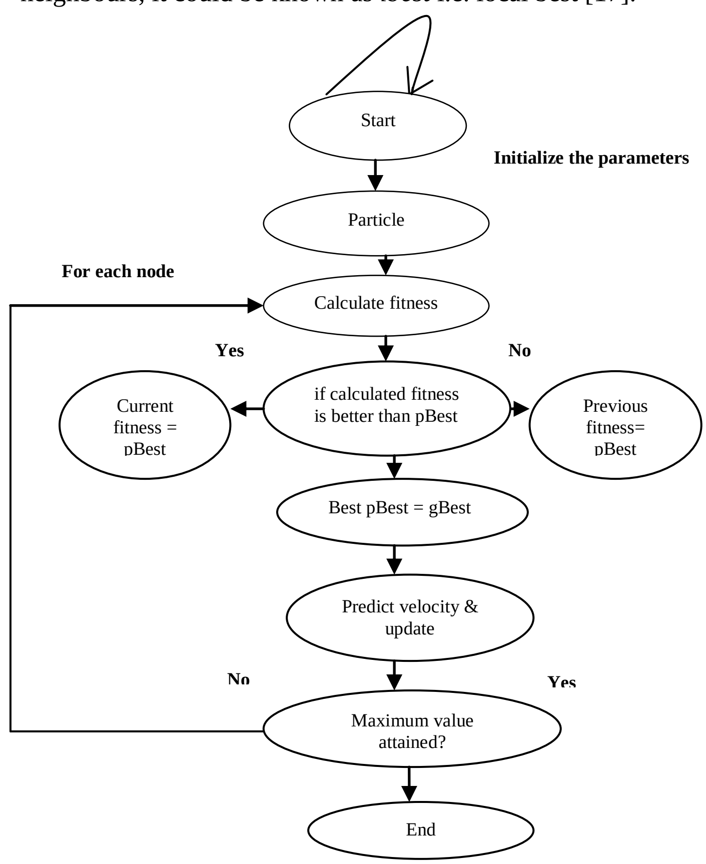

Fig. 2. State machine diagram of PSO Algorithm

1. Prediction of number of clusters in the network

Let *(X,Y)* be the sensing region and *r* be the coverage of any sensor node. Fig. 3 shows a sample sensor network. It is divided into

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

smaller portions called cluster with radius r. Let *(x,y)* be the coordinates of a cluster in a sensing region.

The total Number of Clusters formed *NC* can be calculated based on the whole network area and size of a cluster.

$$NC = XY / xy \qquad (3)$$

where,
XY be the network area and *xy* be the area of the cluster
Let the value of *x=y=t*, Eq. 3 can be written as

$$NC = XY / t^2 \qquad (4)$$

From the right angled triangle shown in Fig. 2, the value of r can be written as,

$$r = t / \sqrt{2} \qquad (5)$$

So the total number of clusters formed can be given as,

$$NC = XY / 2r^2 \qquad (6)$$

This is for the lower bound. The same value is calculated for the upper bound region also. Equation 6 is used for calculating the number of clusters formed in upper bound as,

$$NC = \{(XY / xy) + (X / x) + (Y / y)\} \qquad (7)$$

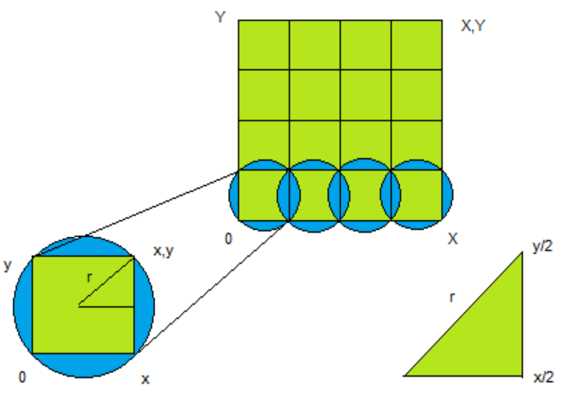

Fig. 3. Clusters in Wireless Sensor Network.

If *x=y=t*, & *X=Y, t=r√2,* the above equation becomes,

$$NC = \{(X^2 + 2\sqrt{2}x * r) / 2r^2\} \qquad (8)$$

The average number of clusters formed in a network can be calculated using the lower bound Equ. 6 and the upper bound Refer (7) values respectively as,

$$NC_{Avg} = \{(X^2 + 2\sqrt{2}x * r) / 2r^2\} \qquad (9)$$

2.Clustering using PSO

Once the nodes are deployed in the sensing region, the Base Station broadcasts a message called *info_collection request* message to all the sensor nodes in the network to collect the node's information. This in turn sends *info_collection reply* message to the Base Station which contains:

a. Position or location of the sensor node, X=(x,y)
b. Velocity of the node V=(v_1,v_2), where v_1 is the average velocity of the sensor node and v_2 is the current velocity
c. Energy of the sensor node, E

The value of position, velocity and energy are maintained and updated at the base station. Then the Base Station makes the sensor nodes to perform clustering. Cluster formation is performed using Particle Swarm Optimization. Here, each node in WSN is assumed as a particle. Individual node formation is prevented by efficient clustering. This can be done by allowing each node to find the nearest neighbor within its radio range and forming clusters. Likewise all the nodes in WSN are allowed to form cluster formation. It results; all the nodes will become a part of any of the cluster. The same process is repeated until all the nodes become a member of any cluster in the network. Average residual value of each particle is predicted.

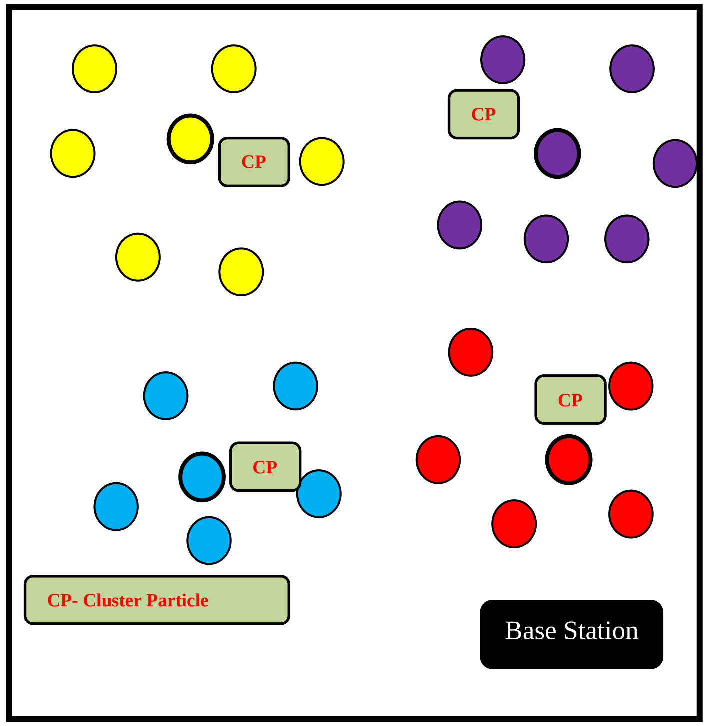

Fig. 4. Cluster and Cluster Particle in WSN

Let us consider a sample space and deploy the particles or sensor nodes in it. Let *N={1,2,3,....m}* be the number of particles considered in the sample space. Particles are created by considering two parameters namely,

a. Position (x,y) and
b. Velocity (v_1,v_2)

The fitness value is calculated for choosing a cluster particle depends on the following three factors namely,

a. Energy of the particle or node E_N
b. Energy of particles or sensors with in a radio range from a particular particle (p)
c. Distance of those particles with in the radio range from a particular particle (p)

Cluster formation takes place by considering the fitness value of each particle as mentioned above. Fig. 4 shows a WSN scenario. It can be seen that for each cluster there is a Cluster Particle. The node which is accessible to maximum number of sensor nodes is elected as cluster particle. Cluster particle is one in which more number of nodes are accessible

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

in its radio range. The cluster particle can be generally referred as cluster head.

The fitness value [18] [19] of each particle can be calculated using Eq. 10 as,

$$fitness = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \quad (10)$$

where,

α_1 and α_2 be any constant value between 0 and 1 and $\alpha_3 = 1 - \alpha_1 - \alpha_2$

$$x_1 = \{\sum (d_N - d_P)\} / C_n \quad (11)$$

where,

$d_N - d_P$ is the distance between the particle and the N[th] node, $N = \{1,2,3...m\}$ & C_n is the number of cluster nodes reachable from the particle *p*.

$$x_2 = E_{Avg}(C_n) / E(p) \quad (12)$$

$$x_3 = 1 / C_n \quad (13)$$

where, *n* is the number of nodes reachable to a particular particle.

Equation 14 shows the updated velocity [17] [18] of each and every particle and is given by,

$$V_{update} = \omega . v_{t-1} + \omega_1 (p_{t-1} - p_t) + \omega_2 (p_{t-1} * p_t) \quad (14)$$

where,
ω - weight of node velocity
ω_1 & ω_2 - weights of node location
v_{t-1} - previous velocity of the node
p_{t-1} - previous position of the node and
p_t - current position of the node.

Location of the particle can be updated with the knowledge of particle's previous location and updated velocity and is given in the Equ. 15.

$$P_{update} = p_{t-1} + V_{update} \quad (15)$$

Fitness function of each particle is calculated for each iteration [17]. Maximum fitness value in each iteration is called as *local_best* and maximum value among all iteration is called as *global_best*. If suppose, *global_best* value is obtained in the l^{th} iteration, fitness values of all particles in that particular l^{th} iteration are taken into account for cluster formation. Node with the maximum fitness value is taken as reference and constructing the cluster by making the nodes in its radio range as its cluster members. The value of global best is broadcasted to each cluster head so that, each head may aware of the global best node. With reference to the node id the information is being transmitted.

Table 1 shows the fitness value of each sensor node in a network in global iteration. It can be observed that, the node with maximum fitness value is 10 and constructing the first cluster by making the neighbor nodes as its cluster member which is shown in Fig. 5. For the network with more number of nodes, say 500, more memory is required to maintain the table. To overcome it, fitness threshold may be computed as,

$$f_T = f_{max}/2 \quad (16)$$

So, it is enough to maintain the table with fitness values greater than or equal to the threshold.

Figure 5 shows the sensor network having nodes with its calculated fitness value using the formula mentioned in Eq. 10. Here, three clusters are formed with reference to the maximum fitness value. It can be seen that, the node which is accessible to maximum number of nodes in a region has maximum fitness value. The same procedure is repeated for entire cluster formation.

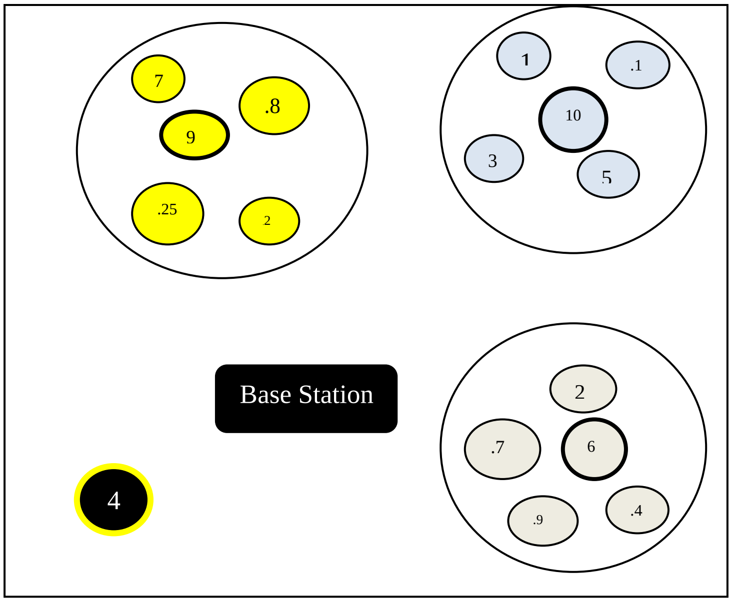

Fig. 5. Cluster Formation using PSO algorithm

TABLE I
SAMPLE FITNESS VALUE FOR THE NODES IN THE GLOBAL BEST ITERATION

Node ID	Fitness (*f*)
50	10
35	9
40	7
2	6
5	5
7	4
10	3

The second highest value is 9 and second cluster is constructed. From the Table I, it can be seen that, the third highest fitness value is 7, but from the Fig. 5, it can be observed that, node with fitness value 7 is already a cluster member in the second cluster. So the next cluster is formed by taking the next fitness value, i.e. 6 is taken for constructing the third cluster and so on.

A node called *Cluster Assistant (CA)* is elected for each cluster with maximum fitness value next to the cluster head or cluster particle. The CA for the first cluster is the one which is having a fitness value next to the cluster particle as 5 which is shown in Fig 4 in the first cluster. The motive of such cluster assistant is to act as a supporting node with the cluster head. These CAs may become a CH if it dies.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

1. Residual node formation reduction using E-OEERP

Figure 5 shows the cluster formation in the proposed method in the first iteration. It can be seen that, there are three clusters in the network. Clustering takes place by considering the node with maximum fitness value. In the constructed network, there exists an individual node with fitness value 4. Such individual node is considered as a cluster head in the next iteration and cluster is formed. The same process is repeated until no or least number of individual nodes remains in the network. The iteration with no individual node or less number of individual node is considered as a *global_best* and the cluster formation is stopped. This results in less number or no number of residual node formation in the network.

Figure 6 shows the flow chart of cluster formation in the proposed E-OEERP.

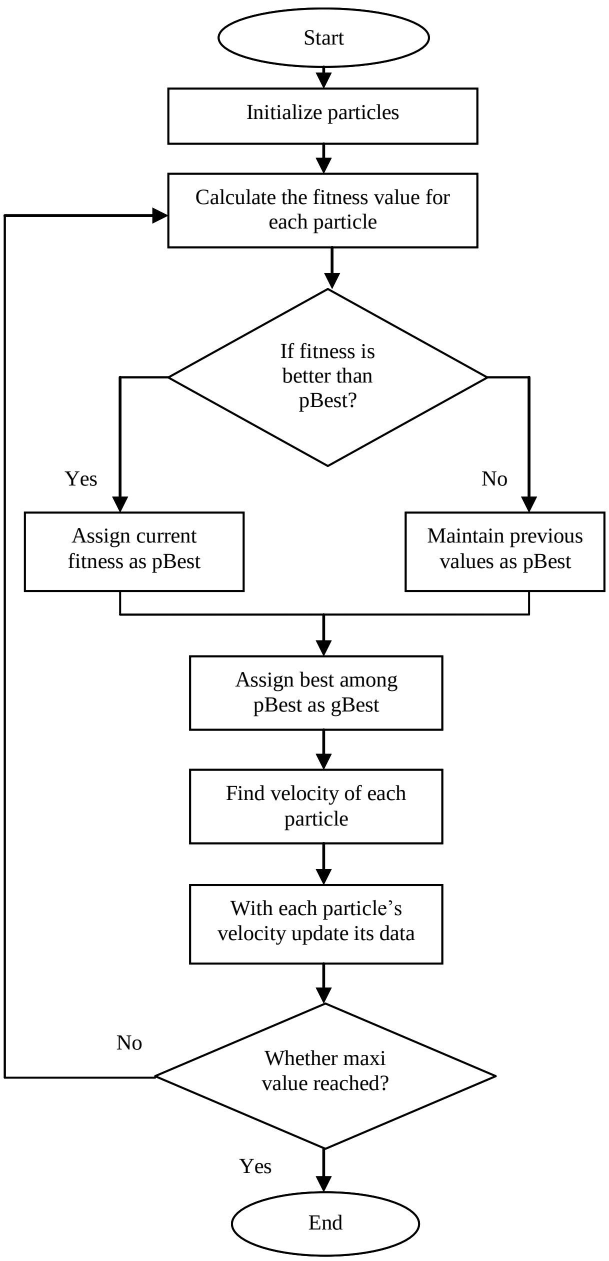

Fig. 6. Flow Chart of Cluster Formation using E-OEERP

B. Gravitational Search Algorithm

Gravitational Search Algorithm is an optimization algorithm used in the proposed method for constructing an optimal path for transmitting the sensed data to the base station. The node which has the data to transmit is called source node. Such node checks for the next best hop to transmit the sensed data towards the destination or Base Station. For finding the next best hop, a *route_request message* is sent to all the neighbors. This *route_request message* contains the information like the node's own *position, velocity and energy* to the neighbor [20]. Neighbor nodes forward the same request to its available neighbors by replacing the received *position, velocity and energy* value by its own value. The same process is repeated until it reaches the Base Station. Gravitational Search Algorithm (GSA) is used for finding the next best hop in the proposed method.

GSA is based on the principles of Law of Gravity by Newton [21]. Newton's Law of Gravity states that, *"Every particle attracts every other particle with a force F which is directly proportional to the product of masses and inversely proportional to the square of distance between them"* [22] [23]. This can be given as,

$$F = G.\left[M_1 M_2 / R^2\right] \tag{17}$$

where,
F - force of a particle
G - Gravitational constant (G = 6.8×10^{-11} m^3 $kg^{-1}s^{-2}$)
M_1 and M_2 - mass of particle 1 & 2 respectively
R - distance between particle 1 and 2.

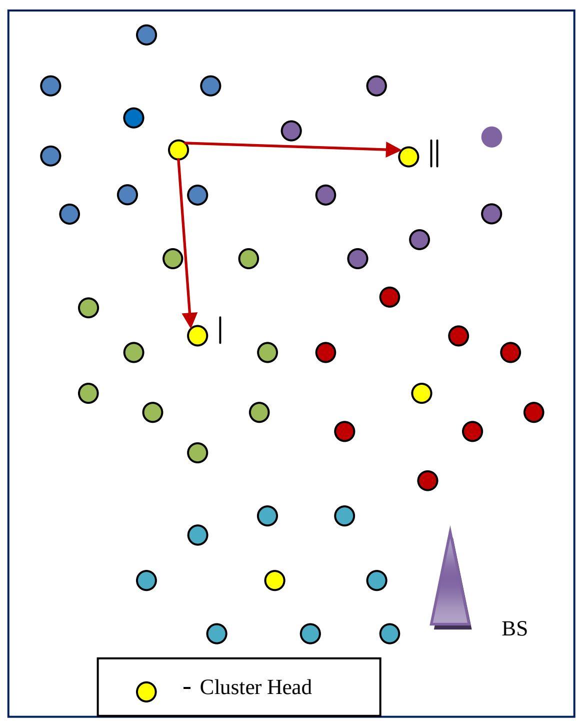

Fig. 7. Calculation of Force between CHs

Once cluster formation and cluster head election take place using Particle Swarm Optimization technique, all the cluster nodes start sensing the data and transmit to the corresponding cluster head. This in turn clusters head start the process of

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

aggregating the sensed data in order to minimize the data redundancies. Before transmitting the sensed data to the Base Station, each cluster head has to predict the shortest available path with high reliability to transmit the aggregated data.

So each cluster head start constructing the routing path by finding the best next hop. The term force is considered between the cluster heads while choosing the best next hop. The force between the clusters heads can be calculated using the formula specified in Eq. 17.

The force of attraction is more for the nearer node than the farthest node. Higher the force of attraction implies that better transmission efficiency and reliability. In addition to that, the node with minimal distance is considered to choose the next hop. From Fig. 7, it can be seen that, the distance between the two cluster heads from a particular cluster head varies. Route construction takes place by considering the next best hop with minimum distance and high force if attraction.

Once the Base Station receives the data, it replies via the next hop with maximum force. The *route_request* message here is a broadcast whereas the *route_reply* message is a unicast.

IV. Results and Discussions

The proposed technique of Enhanced - Optimized Energy Efficient Routing Protocol (E-OEERP) concept with PSO and GSA is simulated using NS-2.32 simulator. Network Simulator is an appropriate software for analysis the work done evaluation of results for wireless networks [22] [23].

TABLE II
Initial Network Parameters

Parameter	Value
No of Nodes	100
Sensing Region	200*200 m
Initial Energy of sensor node	200J
Radius of cluster (r)	30m
Sensing range	36m
Packet size	512 byes
Transmission Power	0.02Watts
Received Power	0.01Watts
Packet Generation Interval	0.1Sec
Transmission Rate	409Kbps

Table II gives the details of initial parameters considered during network setup. During cluster formation, the number of residual nodes for each phase is calculated for both proposed as well as for the existing protocols and compared. A novel method of cluster formation is employed using Particle Swarm Optimization in the proposed E-OEERP. Based on the fitness value of the nodes, cluster formation takes place. It reduces the number of residual nodes in the network. Also by reducing such residual nodes, total energy consumption is reduced and results in better network lifetime. First the number of residual node formation is analyzed for the proposed and the existing protocols. Also the network parameters like total energy consumption, throughput, packet delivery ratio and overall network life time in the network are compared and analyzed.

1. Residual nodes comparison

Cluster formation is performed based on the fitness value in the proposed work. Priority is given to the individual node in each iteration and forming cluster by considering such individual node as cluster head. The same process is repeated for every iteration which results in probably less or even no individual nodes in the network.

The iteration with no residual node or less residual nodes is considered as a *global_iteration* and cluster formation process stopped. The resultant residual node formation at the end of the iteration is shown in Fig. 8. The graph which infers that, the proposed E-OEERP results in less number of residual node formations than existing protocols. As all the nodes become a member of any of the cluster, the average network life time will be improved.

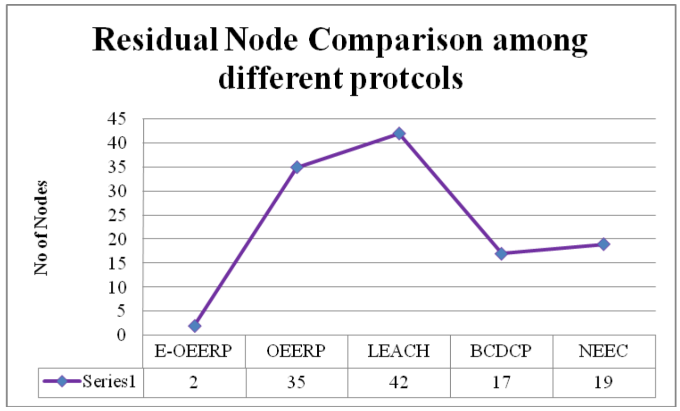

Fig. 8. Residual Node comparison for different protocols

Cluster or Load balancing is the factor which is the average number of balanced nodes in each cluster in the network. This is shown in Fig. 9 for various protocols. It can be seen that, the load balancing ratio for the proposed E-OEERP is better when compare to rest of the existing protocols. And the cluster formation balancing is very less for NEEC protocol when compare to all other protocols.

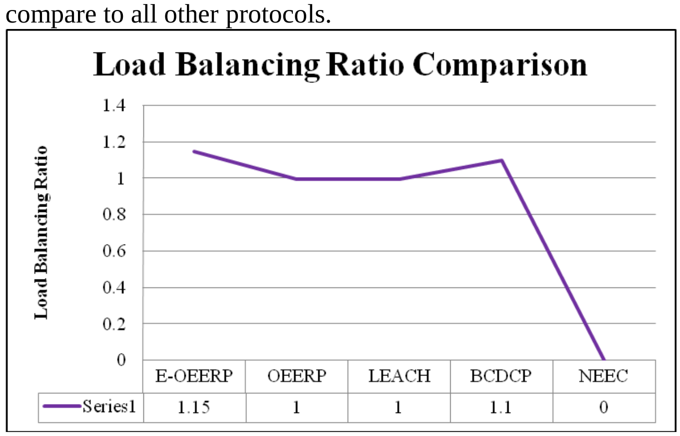

Fig. 9. Load Balancing Ratio

2. Performance analysis

In addition to the reduced number of residual nodes, different network parameter analysis is being done for the proposed and existing protocols. Parameters like Total Energy Consumption, Throughput, Packet Delivery Ratio, Overall Network lifetime, Normalized Control Overheads are compared for the proposed and the existing protocols.

The energy consumption of a node is based on sensing, computing and communication. The energy consumption for a node can be calculated as

$$E_c = E_i - E_r \tag{18}$$

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

where,

E_c - Energy consumed

E_i - Initial energy of the sensor node and
E_r - Remaining energy available of the node after sensing and communication operation.

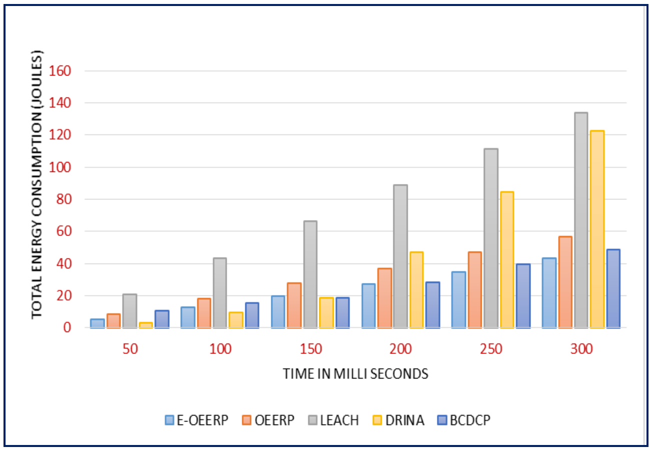

Fig. 10. Total Energy Consumption at different time slots

Similarly the total energy consumed for all the nodes in the network can be calculated as,

$$\sum E_{consumed} = \sum\left(E_{initial} - E_{remaining}\right) \tag{19}$$

Total Energy Consumption for the sensor nodes at different time slots are measured for the proposed and the existing protocols which is shown in Fig 10. The total energy consumption increases as number of nodes increases. There is a gradual increase in the energy consumption for each protocol. From the Fig.10, it can be predicted that the Total Energy Consumption of the proposed E-OEERP is less when compare with other existing protocols. Less energy consumption results in better network lifetime.

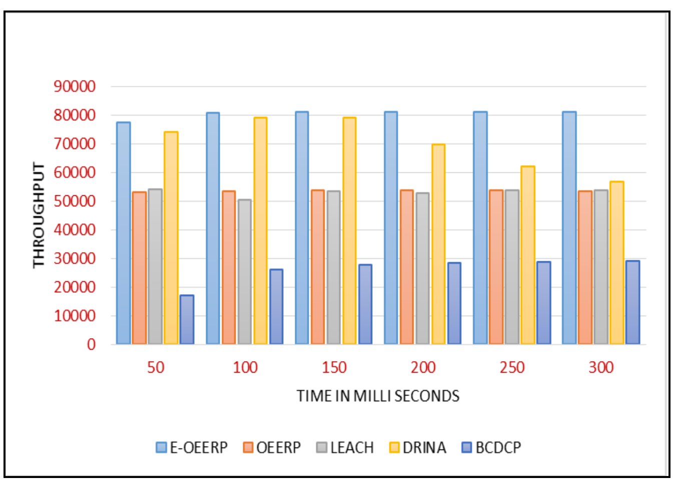

Fig. 11. Throughput at different time slots

Figure 11 shows the throughput comparison of the proposed E-OEERP and the existing protocols. An effective system will have better throughput value. Throughput is defined as how effective the data is being delivered to the designated receiver or base station effectively. It is defined as the number data is being transmitted in bits per second (bps or b/s). The graph shows that, throughput of the proposed work is better than the existing protocols.

Higher the number of received packets increases, the PDR ratio which improves the performance of the system. The Packet Delivery Ratio (PDR) can be calculated as,

$$PDR = RX_{packets} / TX_{packets} \tag{20}$$

where,

$TX_{packets}$ is the number of packets transmitted and

$RX_{packets}$ is the number of packets received. From Fig. 12, it is clearly seen that the PDR of the proposed work is better when compared to various existing protocols at different time slots. For an effective system, the packet delivery ratio should be maximum.

Energy efficient routing protocols in WSN should be designed in an efficient manner in order to improve the network lifetime. The network lifetime is decided by the effective usage of the sensor node in the network.

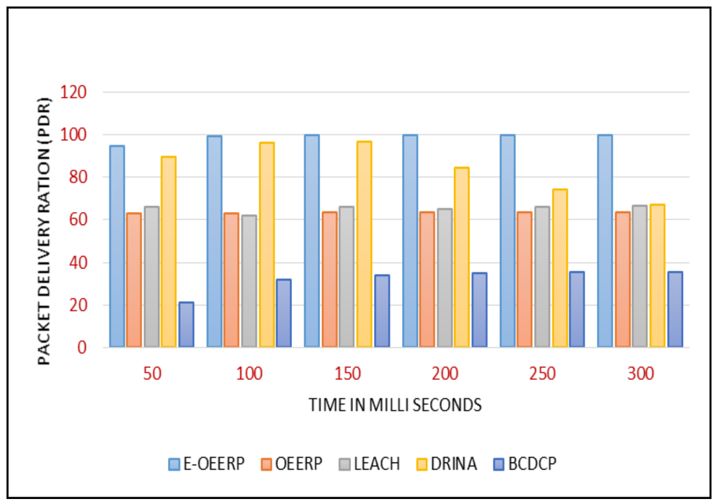

Fig. 12. Packet Delivery Ratio at different time slots

Sensor node in the sensing region is used to perform sensing, processing and communication. The overall network lifetime is based on the above said factors. The network lifetime can be improved by avoiding the sensor node to transmit raw data. This can be achieved by,

- aggregating the sensed data to eliminate the data redundancies
- eliminating the control overheads messages and
- avoiding the long distance transmission

If a network is constructed by considering the above said factors, the overall network lifetime can be improved. These factors are included in the proposed method and the overall network life time is improved. From Fig. 13, it can be seen that the overall lifetime of E-OEERP is better than the existing protocols.

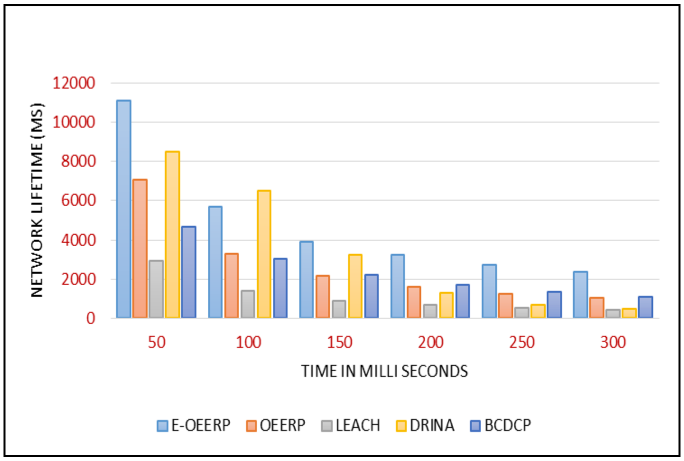

Fig. 13. Overall Network Lifetime at different time slots

The overall network lifetime of the wireless sensor network can be improved by properly making the sensor nodes radio to be in either in ON (Active) or OFF (Sleep) mode. The proposed work provides better lifetime than other protocols.

V. Conclusion

An Enhanced Optimized Energy Efficient Routing Protocol (E-OEERP) is proposed in this paper. In the existing OEERP [6], the individual node formation takes place during cluster formation. And such individual nodes can become a member of any cluster during next cluster formation and some other node may become as an individual node. Though the percentage of individual nodes varies from one time slot to other, it is a major drawback while considering the network lifetime. Such nodes may die earlier as it has to transmit the sensed data either directly to the Base station or after finding the best next hop. These individual nodes in WSN are eliminated by using Particle Swarm Optimization in the proposed work. This can be done by finding the fitness value of each and every node in the network. A new node called Cluster Assistant is introduced with Cluster Head in the proposed method. It act as a coordinator node for the corresponding Cluster Head. Using Gravitational Search Algorithm, the parameters like distance and force between the sensors nodes are taken into consideration for finding the next best hop. Simulation results show the better performance of the proposed work than the existing routing protocols. For mobile WSN, the same work can be used for eliminating individual node formation during clustering.

References

[1] Kiran Maraiya, Kamal Kant and Nitin Gupta, "Application based Study on Wireless Sensor Network," *International Journal of Computer Applications*, vol. 21, no. 8, pp. 9-15, May 2011.

[2] Antonio-Javier Garcia-Sanchez, Felipe Garcia-Sanchez, Fernando Losilla, Pawel Kulakowski, Joan Garcia-Haro, Alejandro Rodríguez, José-Vicente López-Bao and Francisco Palomares, "Wireless Sensor Network Deployment for Monitoring Wildlife Passages," *Sensors Journal*, vol. 10, no. 8, pp. 7236-7262, 2011.

[3] Anahit Martirosyan, Azzedine Boukerche and Richard W. Nelem Pazzi, "A Taxonomy of Cluster-based Routing Protocols for Wireless Sensor Networks," in *Proc.* ISPAN' 08 International Symposium on Parallel Architecture, Algorithm, and Networks (*published in ACM Digital Library*), pp. 247-253, 2008.

[4] Jamal N. Al-Karaki, Ahamed E Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey", *IEEE Wireless Communication*, ISSN: 1356-1284, vol. 04, pp. 6-28, Dec. 2004.

[5] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishna, "Energy-Efficient Communication Protocol for Wireless Micro sensor Networks," in *Proc.* 33rd Hawaii International Conference on System Sciences, Massachusetts Institute of Technology, Cambridge, Jan 2000.

[6] K. Kishan Chand, P Vijaya Bharati and B. Seetha Ramanjaneyulu, "Optimized Energy Efficient Routing Protocol for Life-Time Improvement in Wireless Sensor Networks", in *Proc. IEEE-International Conference on Advances in Engineering, Science and Management (ICAESM March 30 & 31), 2012*, pp. 245-249.

[7] Jelicic, V, Magno, M. Brunelli, D. Paci, G.; Benini, L., "Context-Adaptive Multimodal Wireless Sensor Network for Energy-Efficient Gas Monitoring**,"** *IEEE Sensors Journal*, vol.13, no.1, pp.328-338, Jan. 2013.

[8] De Vito, S.Di Palma, P. Ambrosino, C. Massera, E. Burrasca, G. Miglietta, M.L.Di Francia, G., "Wireless Sensor Networks for Distributed Chemical Sensing: Addressing Power Consumption Limits With On-Board Intelligence**,"** *IEEE Sensors Journa*l, vol.11, no.4, pp.947-955, April 2011.

[9] Shio Kumar Singh, M P Singh, "Routing Protocols in Wireless Sensor Networks - A Survey," *International Journal of Computer Science & Engineering Survey (IJCSES), 1(2)*, pp. 63-83, Nov 2010.

[10] Ademola P. Abidoye1, Nureni A. Azeez, Ademola O. Adesina1, Kehinde K. Agbele, "ANCAEE: A Novel Clustering Algorithm for Energy Efficiency in Wireless Sensor Networks," *Scientific Research, Wireless Sensor Network, 3(9)*, pp. 307-312, Sep. 2011.

[11] Soumen Chatterjee, Mohan Singh, "A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks," *Int. J. Advanced Networking and Application and in Special Issue of NCETCSIT (2011, Dec) in Bapurao Deshmukh College of Engineering, Sevagram. 3(5), 2012*, pp. 12-18.

[12] Poonam Sadafal, R.H Borhade Vishal, "Secure Clustering Algorithm for WSN," *International Journal of Emerging Science and Engineering*, vol. 2, no.2, pp. 1-3, Dec 2013.

[13] Dongfeng Xie, Qianwei Zhou, Xing You, Baoqing Li, and Xiaobing Yuan, "A Novel Energy-Efficient Cluster Formation Strategy: From the Prespective of Cluster Member," *IEEE Communication Letters*, vol. 17, no. 11, pp. 2044-2047, Nov 2013.

[14] J. Kennedy, and R.C. Eberhart, "Particle Swarm Optimization," in *Proc IEEE International Conference on Neural Networks*, NJ: Piscataway, pp. 1942–1948, 1995.

[15] Y. Del Valle, G. K. Venayagamoorthy, S. Mohagheghi, J. C. Hernandez, and R. Harley, "Particle Swarm Optimization: Basic concepts, variants and Applications in Power Systems," *IEEE Trans. Evol. Comput.*, vol. 12, no. 2, pp. 171–195, Apr. 2008.

[16] Raghavendra V. Kulkarni, and Ganesh Kumar Venayagamoorthy, "Particle Swarm Optimization in Wireless-Sensor Networks: A Brief Survey" *IEEE Trans. on Systems, Man, and Cybernetics—Part C: Applications and Reviews*, vol. 41, no. 2, pp. 262-267, Mar. 2011.

[17] X. Wang, S. Wang, and J. J. Ma, "An Improved co-evolutionary Particle Swarm Optimization for Wireless Sensor Networks with Dynamic Deployment," *Sensors*, vol. 7, pp. 354–370, 2007.

[18] Jun Yang, Hesheng Zhang, Yang Ling, Cheng Pan and Wei Sun, "Task Allocation for Wireless Sensor Network using Modified Binary Particle

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JSEN.2015.2416208, IEEE Sensors Journal

Swarm Optimization," *IEEE Sensor Journals*, vol.14, no.3, pp.882-892, Mar. 2014.

[19] Yang G. Kim and Myung J. Lee, "Scheduling Muti-Channel and Multi-Timeslot in Time Constrained Wireless Sensor Network via Simulated Annealing and Particle Swarm Optimization," *IEEE Communication Magazine, Ad Hoc and Sensor Networks*, ISSN: 0163-6804, vol.14, pp.122-129, January 2014.

[20] Marjan Kuchaki Rafsanjani, and Mohammad Bagher Dowlatshahi, "Using Gravitational Search Algorithm for Finding Near-optimal Base Station Location in Two-Tiered WSNs," *International Journal of Machine Learning and Computing, 2(4)*, pp. 377-380, Aug. 2012.

[21] Esmat Rashedi, Hossein Nezamabadi-pour and Saeid Saryazdi, "GSA: A Gravitational Search Algorithm," *Information Sciences, Elsevier, 179*, pp. 2232–2248, 2009.

[22] Taher Niknam, Mohammad Rasoul Narimani, Rasoul Azizipanah Abarghooee and Bahman Bahmaini-Firouzi, "Multiobjective optimal Reactive Power Despatch and Voltage Control: A New Opposition-Based Self Adaptive Modified Gravitational Search Algorithm," *IEEE System Journals*, vol. 7, no.4, pp. 742-753, Dec 2013.

[23] Chaoshun Li, Jianzhong Zhou, Bo Fu, Pangao Kou and Jian Xiao, "T-S Fuzzy Model Identification With Gravitational-Search Based Hyperplane Clustering Algorithm," *IEEE Transaction on Fuzzy Systems*, vol 20, no. 2, pp. 305-317, Apr. 2012.

[24] Namuduri, K, "Analytical Estimation of Path Duration in Mobile Ad Hoc Networks" Sensors Journal, IEEE, vol. 12 , no. 6, pp. 1828 – 1835, 2012.

J.Rejina Parvin received her Bachelor Degree in the stream of Electronics and Communication in the year 2007 and M.E in the stream of Network Engineering in the year 2009 from Anna University, Chennai, Tamil Nadu, India. She is currently doing her Ph.D (Part Time Mode) under Anna University, Chennai. She is currently working as an Assistant Professor, Dept of Electronics and Communication Engineering at Dr. N.G.P Institute of Technology, Coimbatore, Tamil Nadu, India. Her research interests are Wireless Sensor Networks, Soft Computing, Control Systems and Wireless Communication.

Dr. C.Vasanthanayaki received her Bachelor Degree in the stream of Electronics and Communication in the year 2007 and M.E in Computer Science from Government College of Engineering, Tirunelveli, Tamil Nadu, India. She received her Ph.D degree from Anna University, Chennai, India in the year 2008. She is an Associate Professor in the Department of Electronics and Communication Engineering, Government College of Technology, Coimbatore, India. Her research area includes Digital Image Processing, Computer Vision and Pattern Recognition and Wireless Sensor Networks. Two scholars have been awarded Ph.D under her supervision. Currently she is supervising seven Ph.D scholars in Full time as well as in Part time mode.