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Apply Firefly Optimization to Increase Period Routing Algorithm in Wireless Sensor Networks

Ibrahim A. Saleh

Dept. of Software Engineering, College of Computer Sciences & Math, University of Mosul, IRAQ

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Abstract: In this paper introduce new algorithm to increase the periods of wireless sensor network (WSNs) lifetime using firefly optimization algorithm. WSNs consist of tiny power and energy inhibited sensor nodes. The sensor's data collected by neighboring sensor nodes have spatial-temporal associations, also has data aggregation technique which used as active method to remove data redundancy. The efficient network has used data aggregation technique by decreasing the amount of data delivery which results in low cost power and longer network lifetime. The research introduces optimal data delivery in WSNs to make data aggregation, control power consumption for each node and maximize the network lifetime. The paper used firefly algorithm (FA) to choose an optimal points of data aggregation to further optimize the result. This algorithm balance the power of sensor nodes and increase the lifetime of the network. Results show that the proposed approach has considerably enhanced the network lifetime.

Keywords: Wireless sensor network, data aggregation, firefly algorithm, sensortime life, maximum lifetime routing.

1. INTRODUCTION

A Wireless sensor network (WSN) contains a lot of sensor nodes which have the ability to communicate among themselves using radio antenna. These nodes have tiny battery power supply and can generate information that needs to be communicated to a sink node (base station) which had limited memory and limited energy source. All applications of sensor networks require the flow of sensed data from multiple sources to a particular station. These nodes are working together towards achieving a common goal of sensing a physical parameter over a large geographic area with more accuracy [1]. WSN contain multi-hop of node power control mechanism, in contrast to typical communication networks. All applications of sensor networks require the flow of sensed data from multiple sources to a particular base station [2]. Control mechanism of each node's power is dynamically adjusting power through the communication nodes. The number of the of Sensor Networks application are widely used and can be seen in different aspects of our lives; fire detectors, security sensors, etc. In WSN there are several wireless sensors which are capable of sensing a special phenomenon in the environment and send the data back to one or several base stations[3].

The main features of WSN that makes it unique are flexibility in terms of the shape of the network and mobility of the sensors without any wires. Beyond this, also wireless network sensor has its own peculiarities according to the data application environment of neighboring nodes collected and due to that a network tend to have a correlation between time and space [3]. Sensor nodes are constrained in energy supply and bandwidth. Thus, innovative techniques that eliminate energy inefficiencies that would shorten the lifetime of the network are highly required. Such constraints combined with a typical deployment of large number of sensor nodes pose many challenges to the design and management of WSNs and necessitate energy at all layers of networking protocol stack [4]. WSN can aggregate data and divided it according to data segmentation and compression order [5]. Sensor networks contain too much data for an end-user. Therefore, it required to process automated methods of combining or *aggregating* the data into set of practices to avoid information overload [6]. In addition data aggregation, also known as *data fusion*, can combine several unreliable data measurements to produce a more accurate signal by enhancing the common signal and reducing the uncorrelated noise [7]. Classification algorithms on the aggregated data might be performed. Acoustic signals are often combined using a *beam forming* algorithm to reduce several signals into a single

E-mail address: dr.i.hadedi63@gmail.com

signal that contains the relevant information of all the individual signals. Large energy gains can be achieved by performing the data fusion or classification algorithm locally, thereby requiring much less data to be transmitted to the base station [8].

In large sensor network, finding optimal aggregation tree is NP-Hard problem to reduction weighted set covering problem. In the Ant-aggregation algorithm given a permutation of source nodes, it constructs aggregation tree associated with a cost which is the local best aggregation tree. The algorithm iterates to search the global best and the convergence of algorithm gives the optimal aggregation tree from combinatorial space. Thus, the best aggregation tree constructed by ant routing in iterations is remembered. Further, giving early aggregation more weight in cost function will give converge in optimal aggregation points [9].

Minimum Energy Routing (MER) is defined as least amount of energy consumed when sending data-packet from source node to destination node. To get minimum energy of routing information to the routes link energy, should be provided by existing minimum energy routes and frequent maintenance of energy cost [10]. Maximum lifetime routing (MLR) of event-driven wireless sensor networks for which events occur infrequently. In such systems, most of the energy is consumed when the radios are waiting for a packet to arrive. Sleep-wake scheduling is an effective mechanism to prolong the lifetime of these energy-constrained wireless sensor networks. However, sleep-wake scheduling could result in substantial delays because a transmitting node needs to wait for its next-hop relay node to wake up. An interesting line of work attempts to reduce these delays by developing “any cast”-based packet forwarding schemes, where each node opportunistically forwards a packet to the first neighboring node that wakes up among multiple candidate nodes [11].

However, Network life time is not suitable for “local maximum’ for the network topology if assumed data can be infinite division, also it increases the overhead the data. Routing algorithms that maximize time life of data should be send in the following attributes:

1. Most of routing algorithms focuses to find easy path with lowest energy. Some time, Network congestion occur raped consumption of nodes path of energy.
2. Dynamic routing algorithms are considering the network as static scenes, but few of these algorithms overhead introduce the addition of clustering and routing maintenance which leads routing is not suitable in some time. The network life time in routing algorithms don't tend to be more suited to such networks.
3. Some geographic routing algorithm used both dynamic routing and save the routing overhead, but this type of algorithm cannot be applied to all network topology with "local maximum problem". On other hand, beam for path geography routing algorithm is limited, the energy consumptions often is not calculated for the optimal path [12].

This paper proposes a new wireless sensor network algorithm for data aggregation and power control by associate lifetime routing with Firefly algorithm. The function of lifetime routing algorithm is optimizing their data aggregation for any node. The aim is to select point with mining energy path called "*data aggregation point*". Data aggregation's point needs very huge discrete solution space. Firefly algorithm (FA) is optimization method on continuous space of varies technique to give a global search. Combined gradient algorithm with converges to get optimal solution for maximum network life time.

In this paper, section two reviews system models including the wireless network attributes while section three describe Maximum wireless sensor network problems in addition to lifetime problem and the solution using Firefly algorithm (FA). Section four proposed methodology algorithm and simulation results, finally section five hold paper conclusion.

2. SYSTEM MODELS

In this work a hypothetical application involves wireless network, energy model, data aggregation and typical of routing.

A. *Wireless Network:*

Figure (1) shows wireless sensor network used in paper configuration. It is modeled as a random undirected graph ***G(V,E)***, where ***V*** (vertical) represents collection of nodes, ***S*** $\in$ ***V***is base station. ***E*** (Edge) indicates the link set between nodes ***d(i,j)*** represents the distance from node ***i***to node ***j***. Each node transmits data continuously for convenience sake, so that $v = V/\{S\}$.

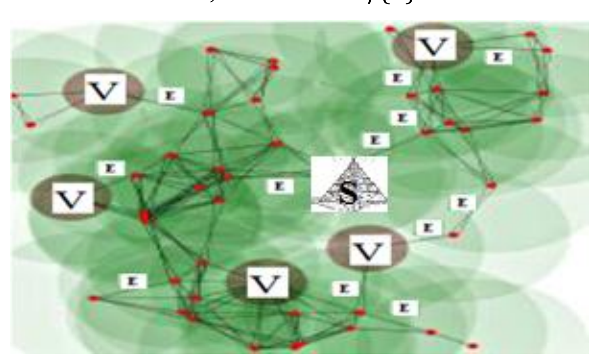

Figure 1. Sample of WNS

B. Energy Model

Assume all nodes have same maximum transmission power (p_{max}) and any node can dynamically adjust it transmission power within range [$0,p_{max}$]. Radio waves adopt with energy of the first order model [13]. Consumed energy for transmission 1 bit from node to other expressed in equation (1)

$$\varepsilon_t(i,j) = \varepsilon_{elec} + e_{amp}d^{\eta}(i,j) \text{......................(1)}$$

Where: ε_{elec} transmitter or receiver that required drive power, ε_{amp} transmitter power gain and η represent the attenuation factor for radio wave propagation, take value in the range $2 \leq \eta \leq 4$. Equation (2) illustrate 1 bit consumed energy when it is received by *node (i,j)*:

$$e_r = e_{elec} \dots\dots\dots\dots\dots (2)$$

Also, note the initial energy e_i is unrestricted of base station in the network node.

C. Data Aggregation Model

Data aggregation is defined as the process of aggregating data from multiple sensors to eliminate redundant transmission. It provide fused information to the base station. Data aggregation usually involves the fusion of data from multiple sensors at intermediate nodes and transmission of aggregated data to base station (sink). In the rest of paper is used term data aggregation to denote process of data gathering with aggregation. We also use term sink to represent base station [12].

While sensor network collected all nodes normally. The data transmit among nodes by association with time and space. Some rooms associated information and save data to achieve compression information transmission overhead approach. Suppose node *i* send data to node *j*, the original data passing to node *j* according to correlation coefficient given by equation (3):

$$\rho(i,j) = 1 - H(i|j)/H(i)\text{................(3)}$$

Where:

H(i) represents size of original data sent by node ***i***

H(i/j) indicates node ***j*** according to its local information[12].

The correlation between relative distance and decreased exponentially node is:

$$\rho\,(i,j) = \exp\left[-\alpha\, d^2(i,j)\right]$$

D. Routing-Model

The new wireless sensor routing model, which takes into account node power control, energy efficiency and path data aggregation techniques. Mutual-evaluation firefly algorithm (MEFA) approach employs maximization value of brightness which is simply proportional to value of objective function. It uses to distribute data aggregation which is reasonably allocated to each node of network [10].

This model differs from the traditional one based on aggregated data clustering task. It focus to the first node for way of minority groups in routing algorithm. Routing based on spanning tree algorithm to transfer data, does not appear in the "local biggest" problem. It does not need to support similar GPS location positioning system shown in figure (2) where node $i \in V$. The neighbor's node denoted N_i. To select a point node as data aggregation by $a_i \in N_i$ collection and record network nodes:$\emptyset = \{\vec{A}\} = \prod_{i \in V} N_i$.

As shown in figure (2), the raw data is passing from node ***i*** to data aggregation point a_i. The a_i point is responsible for data aggregation of node ***i*** in order to reduce energy consumption of network. The aggregated data is transmitted to base station ***S*** by minimum energy path. Data is transferred across minimum energy. Virtually all minimum energy paths constitute a base of a tree with minimum power spanning tree root.

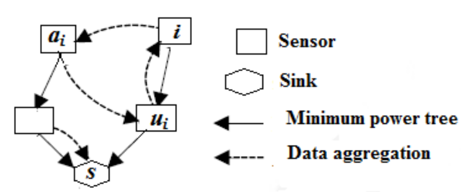

Figure 2. Typical of Routing in Wireless Sensor Network

In practical applications routing can be achieved through the following steps:

Step 1: Each node in WSN send messages to neighbors nodes and estimate link energy $\varepsilon_t(i,j)$, and data correlation coefficient $\rho(i,j)$.

Step 2: The base station initiates distributed minimum spanning power and collect network energy that consumed for each link and data correlation coefficient.

Step 3: The network node data aggregation points are calculated indecision vector optimization by basestation (sink) or outer node.

Step 4: Base Stations along spanning tree will announce decision vector data aggregation point to whole network, where each node corresponds to just release data aggregation points to its child nodes in tree.

Step 5: Finally, each nodes start collecting data, and in accordance with optimization of data aggregation points spanning path decision vector and determined transfer data.

3. MAXIMUM WIRELESS SENSOR NETWORK ROUTING PROBLEMS LIFETIME

A. *description of problem*

Assuming the initial energy of sensor nodes $\vec{\boldsymbol{E}} = \{\boldsymbol{e_i}\}_{i\in V}$ and the rate of original data generation $\vec{\boldsymbol{R}} = \{\boldsymbol{r_i}\}_{i\in V}$, then the corresponding data aggregation point in decision-making vector is $\vec{A} \in \emptyset$.The aggregate data rate of node $\boldsymbol{i}\ \gamma\ \boldsymbol{j}$ (unit is bps) comprises of two parts: one is original data from neighbornode compressed, secondis aggregateddata forwarded by child node $\boldsymbol{w_h}$ich express in equation (3):

$$\gamma_i = \sum_{i=a_i, j\in v} r_j[1-\rho(j,i)] + \sum_{i=u_j, j\in V} \gamma_j \ldots\ldots\ldots\ldots\ldots (3)$$

Overall aggregate data can be represented by the formula:

$$W_i(\vec{A}) = \frac{\{r_i\varepsilon_t(i,a_i) + \gamma_i = \sum_{i=a_i,j\in v} r_j[1-\rho(j,i)] + \sum_{i=u_j,j\in V}\gamma_j\}}{e_i} \ldots\ldots (4)$$

Where $\boldsymbol{r_i\varepsilon_t(i,a_i)}$ represents consumption energy of its data aggregation points in equation (3) for node$\boldsymbol{i}$when sending raw data to indicate selection section. Receiving raw data point $\boldsymbol{i}$and forwarding aggregated data compression from neighbor node

The $\sum \boldsymbol{\gamma_j}[\boldsymbol{\varepsilon_r} + \boldsymbol{\varepsilon_t}(\boldsymbol{i},\boldsymbol{u_i})]$ represents node $\boldsymbol{i}$ receive aggregate data from its child nodes and forward it as energy consumption of parent node $\boldsymbol{u_i}$. Thus the lifetime of node$\boldsymbol{i}$ is obtained by expression:

$$t_i(\vec{A}) = 1/\ w_i(\vec{A}) \ldots\ldots\ldots\ldots\ldots (5)$$

Life of problem objective function (namely life of network) can be represented as:

$$T_{net}(\vec{A}) = \min_{i\in V}\{t_i\ (\vec{A})\} \ldots\ldots\ldots\ldots (6)$$

Thus, maximum lifetime of wireless sensor networks routing problem can be summed up as a discrete space, non-linear planning issues: solving optimal decision vector A^* in the discrete space Ω. The objective function T_{net} *(A)*. To obtain themaximum value of the network, maximizingof life and the optimal decision vector can be represented by the following formula [16]:

$$T_{net\_max} = \max\{\min\{t_i(\vec{A})\}\} \ldots\ldots (7)$$

While

$$\vec{A}^* = argmax\{\min\{t_i(\vec{A})\}\} \ldots\ldots (8)$$

B. *Firefly Algorithm – Maximum lifetime routing Algorithm (FA-MLR)*

FA-MAL algorithm is Meta heuristic approach devised to find optimal solutions used to solve problem. FA is a nature inspired algorithm, which is based on the flashing light of fireflies. The flashing light helps fireflies for finding mates, attracting their potential prey and protecting themselves from their predators. The swarm of fireflies will move to brighter and more attractive locations by flashing light intensity that associated with the objective function of the problem considered in order to obtain efficient optimal solutions. Firefly algorithm is **a** Meta heuristic algorithm, inspired and established on social flashing behavior of fireflies. The primary purpose for a firefly's flash is to act as a signal system to attract other fireflies [14].

To formulate the firefly algorithm, there are three idealized rules:

1- All fireflies are unisexual, so that one firefly will be attracted to all other fireflies.

2- Attractiveness is proportional to their brightness, and for any two fireflies, the less bright one will be attracted by (and thus move to) the brighter one; however, the brightness can decrease as their distance increases.

3- The brightness of a firefly is determined by the landscape of the objective function. For a maximization problem, the brightness can simply be proportional to the value of the objective function [14].

In FA algorithm, there are two important points: the difference in light intensity and creation of attractiveness. For simplicity, that the attractiveness of a firefly is determined by its brightness which in turn is connected with the encoded objective function, figure (2) shown the pseudo code of firefly algorithm.

Objective function $T_{net} = (A)$

Generate initial population of fireflies *xi* (i = 1, 2, ...,*n*)

Light intensity *Ii* at *xi* is determined by *f*(*xi*)

Define light absorption coefficient *γ*

While *t* <MaxGeneration (G)

For *i* = 1 :*n* all *n* fireflies

For *j* = 1 :*I* all *n* fireflies

If (*Ij*>*Ii*) Move firefly *i* towards *j* in *d*-dimension;

Attractiveness varies with distance *rij* via *exp*[−*γrij*]

Evaluate new solutions and update light intensity

End if

End for *j*

End for *i*

Rank the fireflies and find the current best

End while

Post process on the best-so-far results and visualization

Since A^* in equation (8) is discrete space $T_{net} = A$) convex function and has discontinuity in space. According to literature, due to WSN topology graph G, the optimal solution can be regarded as connected random distances graph with optimal gradient [20].

The probability distribution for nodes connection at any section will link at least two points. The expansion of network scale[IS]progressless than value in two discrete spacestoward node:

$$\emptyset = \prod |\boldsymbol{N_i}| = \boldsymbol{\Omega}(\boldsymbol{2}^{|\boldsymbol{V}|})$$

Where Ω represents a progressive lower bound. Therefore, obviously when use an exhaustive search approach cannot give good end, for this reason using modern heuristic algorithm as relatively mature firefly algorithm [18].

The goal of firefly algorithm is to find optimal solution, soits ability to carry out search in field to find single point is relatively limited. The objective of fitness function employ the minimize of intra-cluster compactness with hamming distance between nodes in same cluster as shown in equation below.

$$N(\overrightarrow{A_0}) = \left\{\vec{A}\,\middle|\,\left|\left|\vec{A} - \overrightarrow{A_0}\right|\right| = 1.\vec{A} \in \emptyset\right\} \ldots\ldots\ldots\ldots\ldots (9)$$

Where:

A: The distance between | A_1 - A_0 |.

To select new decision vector from any nodes with its neighbor can be obtained by gradient equation below.

$$\nabla(\overrightarrow{A_1}, \overrightarrow{A_0}) = [T_{net}(\overrightarrow{A_1}) - T_{net}(\overrightarrow{A_0})]/||\overrightarrow{A_1} - \overrightarrow{A_0}|| \ldots (10)$$

In order to make the converges algorithm fast in difference network lifetime, we have $\boldsymbol{A_0}$ decision vector to select $\boldsymbol{N(A_o)}$ decision vector in the neighborhood, to obtain value of gradient vector, soit reached maximum value of steepest gradient ascent algorithm [15].

4. SIMULATION

In this paper, simulation and comparison among the following routing algorithms is applied:

1. (FA-MLR)Algorithm.
2. (MER) Algorithm.
3. (MLR) Algorithm.
4. (MEFA) Algorithm

A. Scene settings

In this paper WSN is modeled as random network with rectangle area (100*100) m^2. All node shave 20-100 sensors with equal initial energy level. The maximum communication distance point is 20m. The wave power model parameters for the first radio ε_{elec} = 50nJ/bit and ε_{amp} =100pJ/bit. Number of radio propagation path attenuation **η=2**.Model of inter-related data using Gaussian random field which ranges parameter **α** is 0.001/m^2and0.01/m^2 (The lower degree of correlation **α**is smaller).

B. Analysis of Results

The scenario of typical network used in figure (3), so the solid line represent minimum link on the path while the dotted line with arrow poly represents selected conditions for node of data point .Nodes are always sending data to closed neighbored points of each other. They have correlated data, for each node allowed to make number of different value for network lifetime.

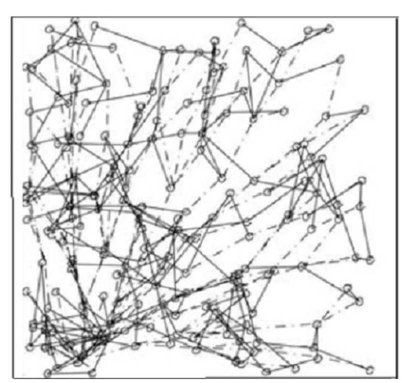

Figure 3. FF-MLR in typical network

As can be seen in the figure (4), the effect of correlation coefficient for different protocols increaselifetime of the network. It showed a gradual downward trend because the data load is proportional increased to number of nodes in network, also when increase size of network lead to more consumption energy of network .

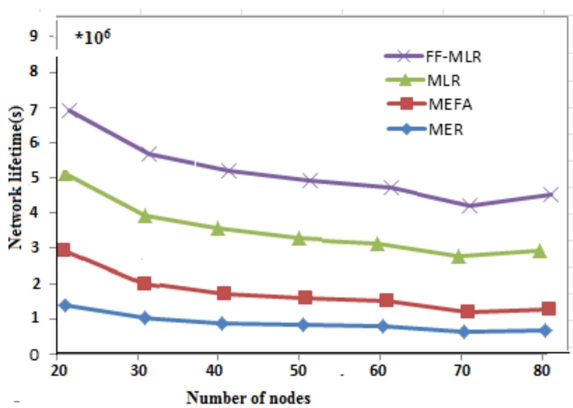

Figure 4a. Network lifetime when α=0.01

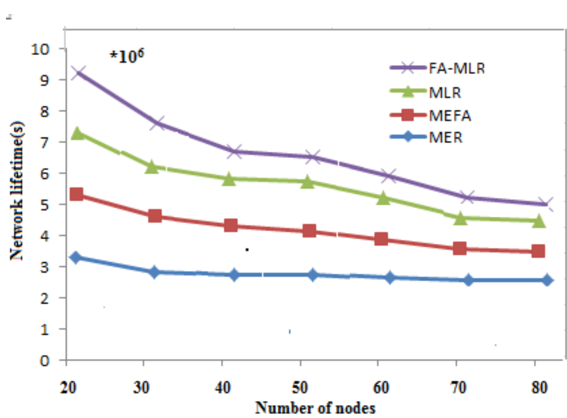

Figure 4b. Network lifetime when α=0.001

C. Results discussion

However, the lifetime of the network can be improved to some extent, by control of free parameters essence MLR algorithms for geographic routing algorithms. The FA-MLR algorithms take into account the relevance of data and energy transmission path.The network lifetime has greatly improved when compared the three algorithms as following:

1. At $\alpha = 0.001/m^2$ the lifetime inFA-MAL algorithmis much better than MER and MEFA algorithms. The lifetime increased from 25% to 56%.
2. At $\alpha = 0.01/m^2$For FA-MLR algorithm has increase from 30%to 65% in lifetime when compared to MER and has increased from 105%to 225% when compared with MEFA algorithm,
3. Whenα value decreased lifetime of the network appears increased as shown in figure (4).

In the case of large correlation it will eliminate a lot of relevant information and reducing network data load which lead to decrease consumption energy. Also it is seen when correlation is small, it rely mainly on balancing power consumption which lead to increase network lifetime. The aggregation data rate increased proportionally with network expanded as shown in figure (5).

Increasing the number of nodes will leads a base station to be more relative fornon-neighboring nodes, and the data transferred via the neighbor nodes need to polymerize data. Handed station, causing increase the data rate of polymerization and the number of nodes increase almost linearly. Figure (5) also shows as α increases the correlation data is reduced, reduce the removed amount of redundant data and resulting in improving the data rate of polymerization. FA-MLR algorithm effectively reduces the aggregate data rate, reducing network load and extend the lifetime of the network.

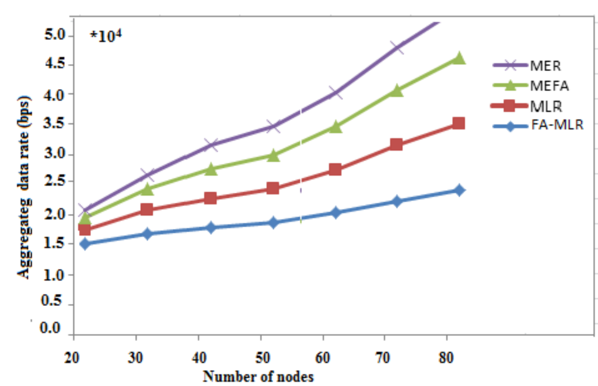

Figure 5a. Aggregated data rate with α=0.01

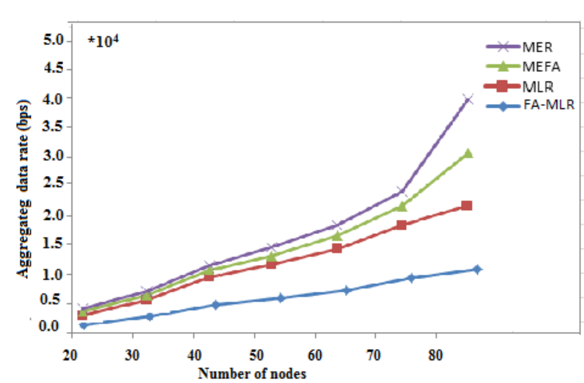

Figure 5b. Aggregated data rate with α=0.001

As seen in Figure (6), a smaller load balancing factor lead to more balances in the energy consumption for each node. FA-MLR algorithm can better balance node's consumption energy, therefore can avoid bottlenecks nodes, prevent fast failure individual nodes and prolong the lifetime of the network. Figure (7) illustrates base station called Band-1 node. Network load is highest energy nodes most likely to become the network bottleneck node to this end. The comparison for load balancing situation Band-1 nodes. It is shown that FA-MLR algorithm have a good balance of load Band-1 node.The node's lifetime difference is small, while the MLR algorithm due to geographic routing is not ideal.

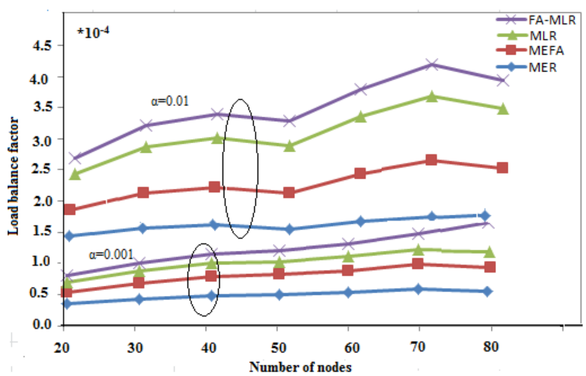

Figure 6. load balance factor

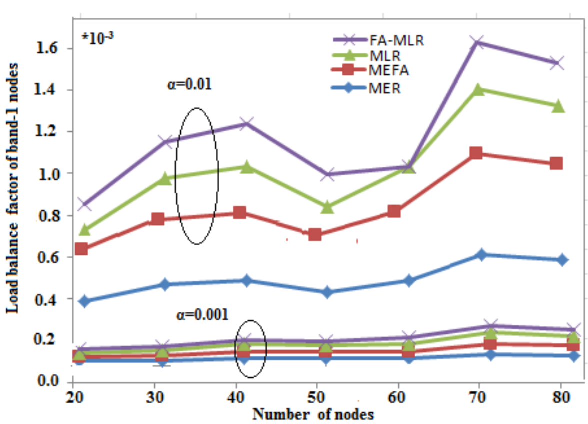

Figure 7. load balance factor of band-1 nodes

In order to study the convergence properties of FAMLR algorithms we defines normalized fitness (optimal fitness) of individuals in each iteration.

1. Firefly algorithm is an optimization procedure with all members with high fitness will perform their jobs efficiently and reach high quality and save their level of energy.
2. When the scale of network is expanded, the decision space is growing, the algorithm stillwork efficiently.
3. The time complexity gradient algorithm is also O ($|V^2$).

5. CONCLUSION

This paper applied a firefly algorithm to increase lifetime, path optimization and lossless data aggregation of node power control used in wireless sensor network. Each sensor node selected data aggregation point to eliminate redundant data between the base stations and submitted to the minimum energy path aggregated data. It takes into account the balance of data aggregation, node energy consumption and efficiency. The firefly algorithm is used to find data aggregation point. The global search combines with discrete space is used to get the approximate optimal decision vector which can consider the maximum distance between aggregation point and members. Results from simulation show that the FA-MAL algorithm gives a better network life when compared to the existing algorithms and significantly reduce the aggregate data rate of the network, balancing the energy consumption of nodes and greatly improves the lifetime of the network.

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Ibrahim Ahmed Saleh: born in Mosul-Iraq in 1963. He rec eived his MSc. degree (in signal and image processing from the University of Mosul, Iraq in 2003 and in 2013 he received his PhD in using artificial techniques in Networking from Mosul University. From 1997 to 2005, he worked at computer Center in Mosul university/ Iraq. Currently he is an Assistant Professor at the Dept. of Software Engineering, College of Computer Sciences & Math, University of Mosul, IRAQ. His interesting in Network and artificial intelligent simulation.