Improving the life time through Firefly based cluster head selection algorithm in WSN's

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Abstract:

In Wireless Sensor Network system Energy Consumption and Life time are the major design issues. Because sensors are usually battery operated; Hence optimization of Energy is very much required to increase the node life time as well as network life time too. Which indirectly improves the performance of the network. Meta heuristic algorithms are one of the best suitable way to optimize in wireless sensor networks (WSN). The proposed algorithm is to analyze the life time and minimizes the energy consumption of the network based on the meta- heuristic algorithm. Clustering is the most prominent data analysis technique to identify homogeneous groups of objects based on the values of their attributes. For clustering, the energy of each individual nodes assume to be similar to that of the light intensity of fireflies in FA algorithm. The movement nature of firefly in FA algorithm is similar to change the location of the cluster head. The movement of less attractive fireflies towards more attractive fireflies is similar to clustering of less energy nodes towards the higher energy nodes. The proposed energy optimization algorithm based on metaheuristic algorithm like firefly which is seen to provide better performance than the traditional direct transmission and LEACH (Low Energy Adaptive Clustering Hierarchy) protocols. The proposed model improves the lifetime of the network and residual energy of the wireless sensor network.

Keywords: WSN, LEACH, Direct Transmission, Cluster Head Selection, meta heuristic algorithms, Firefly algorithm.

1. Introduction:

Wireless sensor networks (WSNs) is an emerging technology that has seen enduring ascent in its utilizations. This is due to its applications in surveillance, environment, and biosphere monitoring. Recent advances in the infrastructure systems have helped connect the world through the smart grid, intelligent networks, smart cities, and intelligent transportation [1]. These setups mentioned have a common component, the internet of things (IoT), where sensor nodes play a critical role, which is then closely coupled with information and communication technologies. An ordinary WSN consists of a large number of miniature, low-power, low-cost sensor nodes (SN) and at least one base station (BS) [2]. The objective of WSN is to screen at least one qualities of a specific range called the region of intrigue or the detecting zone. Correspondence range, adaptability, and energy efficiency are significant requirements of WSN. Sensors are for the most part furnished with non-rechargeable batteries, and once sent in the zone of intrigue they continue working until they come up short on power. The sensor nodes are frequently deployed in the remote or hostile environment, so replacement of their battery is not feasible. WSNs use their energy in several ways, yet data transmission is one of the biggest causes for energy expenditure. Consequently, the design of an energy-efficient protocol for WSN is one of the biggest difficulties in increasing the system's life expectancy. Besides, the lifetime can be influenced by system scale. As the scale builds, the dependability of the system turns out to be critical. Diverse strategies have been recommended for prolonging the lifetime of the sensor network. Clustering is one of the most proficient ways to deal with energy utilization in WSN [3], and a hierarchical architecture design gives a strong answer for the network lifetime and stability issues. In a hierarchical architecture design, the network is divided into various layers and different nodes perform distinctive tasks. The sensing area of the WSN is partitioned into several groups, called clusters. Each of these clusters consists of cluster members (CM) and a single cluster head (CH) (see Fig. 1). First, the cluster head (CH) gathers the data from every cluster member and aggregates the gathered data. Next, it sends the aggregated data to the remote base station (BS). In addition, the BS is connected to a private network or a public network. This approach of clustering has numerous benefits. First, it helps in discarding redundant data at the CH level itself. Thereby decreasing the energy consumption of each node due to the reduced data transmission. Second, the network's scalability is increased significantly. Finally, it also conserves the bandwidth as the sensor nodes communicate directly to their cluster head and this decreases the number of redundant messages amongst the sensor nodes.

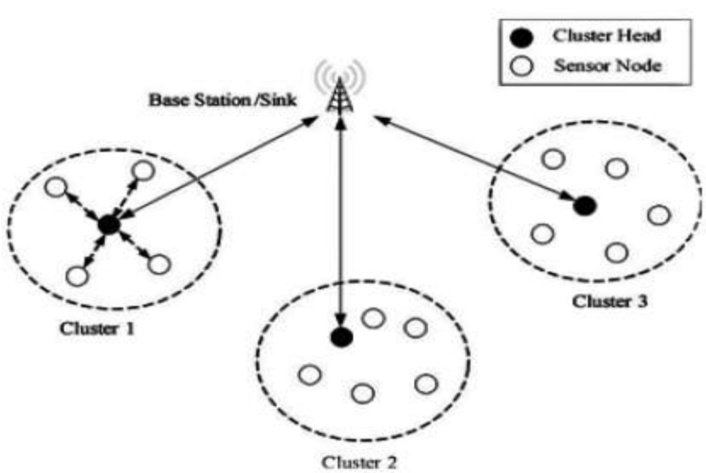

Fig. 1. Clustered hierarchical architecture

2. Clustering Approaches

3. Background.

Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH algorithm divides wireless sensor network into several clusters. The algorithm introduces a random clustering scheme for wireless sensor network (Heinzelman et al 2000). It is a dynamic clustering routing method where nodes are selected as cluster head randomly based on a threshold value calculated using Equation 2.1. Main techniques of LEACH protocol include algorithms for distributing cluster forming, adaptive cluster forming, and cluster header position changing. The technique of distributing cluster forming ensures self-organization of most target nodes. The adaptive cluster forming and cluster header position changing algorithms ensure to share the energy dissipation fairly among all nodes and prolong the lifetime of the whole system in the end.

In LEACH, the nodes organize themselves into local clusters, with one node acting as the CH. All non-cluster head nodes must transmit their data to the cluster head, while the cluster head node must receive data from all the cluster members, perform signal processing functions on the data e.g. data aggregation and transmit data to the remote base station. Therefore being a cluster head node is much more energy intensive than being a non-cluster head node. In the scenario where all nodes are energy limited, if the cluster heads were chosen a priori and fixed throughout the system lifetime, the cluster head sensor nodes would quickly use up their limited energy, such method is known as static clustering method. Once the cluster head runs out of energy, it is no longer operational. Thus, when a cluster head node dies (e.g. uses up all its battery energy) all the nodes that belong to the cluster lose communication ability.

Thus, LEACH incorporates randomized rotation of the high energy cluster head position such that it rotates among the sensors in order to avoid draining the battery of any one sensor in the network. In this way the energy load associated with being a cluster head is evenly distributed among the nodes. Media access in LEACH was chosen to reduce energy dissipation in the non-cluster head nodes. Since the cluster head node knows all the cluster members, it can create a TDMA schedule that tells each node exactly when to transmit its data. This allows the nodes to remain in the sleep state with internal modules powered down, as long as possible. In addition using a TDMA schedule for data transfer prevents intra cluster collisions. The operation of LEACH is divided into rounds. Each round begins with a set up phase when the clusters are organized followed by a steady state phase where several frames of data are transferred from the nodes to the cluster head and on to the base station. The nodes must all be time synchronized in order to start the set up phase at the same time. In order to minimize the set up overhead, the steady state phase is long compared to the set up phase.

2.1.1.1 Determining cluster head nodes

Initially, when clusters are being created, each node decides whether or not to become a cluster head for the current round. This decision is based on the suggested percentage ‘p’ of cluster heads for the network (determined a priori) and the number of times the node has been a cluster head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster head for the current round (HaimingYang BiplabSikdar 2007).

The threshold is set as in Equation 2.1.

$$T(n)=\begin{cases}\dfrac{P}{1-P\left(r \bmod \left(\dfrac{1}{p}\right)\right)} & \text{if } n\in G \\ 0 & \text{otherwise}\end{cases} \quad (2.1)$$

Where, p is desired percentage of cluster heads, r is the current round, G is the set of nodes that have not been cluster heads in the last rounds

Using this threshold, each node will be a cluster head at some point within rounds. During round 0 (r = 0), each node has a probability ‘p’ of becoming a cluster head. The nodes that are cluster heads in round 0 cannot be cluster heads for the next rounds. Thus the probability that the remaining nodes are cluster heads must be increased, since there are fewer nodes that are eligible to become CHs. After -1 rounds, T = 1 for any nodes that have not yet been clusterheads, and after rounds, all nodes are once again eligible to become clusterheads. Future versions of this work will include an energy-based threshold to account for non-uniform energy nodes. In this case, it is assumed that all nodes begin with the same amount of energy and being a cluster head removes approximately the same amount of energy for each node. However LEACH was one of the best approaches for cluster head selection and energy balancing, but still it has certain limitations as describe in the next section. LEACH is a completely distributed approach and requires no global information of network. There are many variants and modification of LEACH developed, which form LEACH family. Some of the modified LEACH (Fan & Song 2007) discussed in the various existing works are Two-Levels Hierarchy for Low-Energy Adaptive (TL-LEACH) (Loscri et al 2005), Energy-LEACH (E-LEACH) (Fan & Song 2007), Centralized Low Energy Adaptive Clustering Hierarchy (CLEACH) (Heinzelman et al 2002), Vice-LEACH (V-LEACH) (Yassein et al 2009), Low Energy Adaptive Clustering Hierarchy Fuzzy Logic (LEACH-FL) (Ran et al 2010), Weighted Low Energy Aggregation Clustering Hierarchy (W-LEACH), (Abdulsalam&Kamel 2010) and Threshold-based LEACH protocol (T-LEACH) (Hong et al 2009).

2.1.1.2 Limitation of LEACH algorithm

Though, the energy consumption is distributed among all the sensor nodes, so many limitations of LEACH are found as follows:

There is a possibility of none of the sensor node in the network selecting itself as a cluster head during some rounds.

There is a possibility of concentration of all the selected cluster heads in only a part of the network.

The even distribution of the cluster heads is not guaranteed.

The clusters are not guaranteed to be of equal sizes.

A balanced cluster head distribution is not guaranteed.

Cluster head selection is not energy adaptive.

Cluster formation, during each round, consumes energy of all the sensor nodes.

Nodes near the cluster boundary are expected to consume more energy as compared to other sensor nodes.

Most of these limitations seem to be encouraged by the basic cluster head selection strategy, of generation of a random number and its comparison with a calculated probabilistic threshold by all the sensor nodes, used in LEACH. The possibility of the random numbers to be generated being either greater or smaller to their respective calculated thresholds may cause none or all of the eligible sensor nodes to select themselves as cluster heads, during some data gathering rounds. In such scenario, all nodes acting as forced cluster heads are required to transmit their sensed and processed data, directly to the distant base station and result in their more energy consumption which, as its consequence, reduces the network lifetime (Younis et al 2003).

DIRECT TRANSMISSION (DT)

Using a direct communication protocol, each sensor sends its data directly to the base station. If the base station is far away from the nodes, direct communication will require a large amount of transmit power from each node. This will quickly drain the battery of nodes and reduce the system lifetime. However the only reception in this protocol occur at the base station, so if either the base station is close to the nodes, or the energy required receiving data is large, this may be an acceptable (and possibly optimal) method of communication (Wang et al 1999).

3.1 Fire Fly Optimization

FFO algorithm is Meta-heuristic algorithms proposed by Dr. Xin She yang at Cambridge University in 2007. It is on the basis of flashing behavior of fireflies14. It finds the particle position. Firefly optimization mainly depends upon these methods:

1. All fireflies are unisex. These attract to each other on the basis of flash light.

2. Attractiveness of fireflies on basis of light directly proportional to its brightness. If there is not found brighter light of fireflies than firefly move randomly.

3. If distance between fireflies increases means light intensity decreases.

4. Objective function related to brightness of firefly. According to inverse square law intensity of light I decrease as distance r between fireflies increases. Intensity (I) inversely proportional to radius as:

$$\mathbf{I \;\alpha\; 1/r2} \qquad \mathbf{(1)}$$

5. Firefly algorithm mainly depends on light intensity and attractiveness. According to inverse square law

$$\mathbf{I(r) = Is / r^2} \qquad \mathbf{(2)}$$

where, Is Intensity of source and r radius (distance between fireflies). But there is fixed light absorption γ

$$\mathbf{I = I_0\, e^{-\gamma r2}} \qquad \mathbf{(3)}$$

I_0 Initial intensity. Firefly's attractiveness β is proportional to the light intensity seen by different fireflies which can be defined as:

$$\mathbf{\beta = \beta_0\, e^{-\gamma r2}} \qquad \mathbf{(4)}$$

where, β0 is attractiveness when radius=0 Light intensity changes with changes in distance as r.

Clustering using Firefly Algorithm

Each node distance calculated on basis of brightness. Each cluster adds nodes on basis of distance from CH form a new cluster and prevent residual nodes. Distance between nodes calculated as: Distance = (X1 -X2)2 (Y1 -Y2)2 ^0.5 (5) In Firefly algorithm, clustering energy of sensor nodes considered as light intensity of fireflies. Sensor which is brighter considered as with maximum energy. Light intensity fireflies move towards brighter intensity fireflies. Similarly, in clustering less energy nodes move towards higher energy nodes. Fireflies move from one location to another location with attraction toward brighter firefly16. The Firefly algorithm improve network lifetime and the throughput of the network with selection of CH on basis of residual energy and nodes in cluster coverage selected on basis of distance

Objective Function $f(x)$, $x=(x_1,x_2,\ldots,x_d)T$

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

Light intensity I_i at xi is determined by $f(x_i)$

Define light absorption coefficient **γ**

while (t< MaxGeneration)

for i=1: n all n fireflies

for j=1: i all n fireflies

if($I_j > I_i$), Move firefly towards j in d-dimension; end if

Attractiveness varies with distance r via exp[-γr]

Evaluate new solutions and update light intensity

end for j

end for i

Rank the fireflies and find the current best

end while

Algorithm 1: Pseudo code for cluster formation and CH selection in firefly.

Simulation Environment

The simulation of the proposed methodology is being done in MATLAB. This technique uses LEACH protocol with FFO and GSA algorithm for simulation in MATLAB. Deployment area with 100 nodes deployed randomly for the simulation of LEACH protocol. In this simulates the previous clustering algorithm with LEACH protocol in which residual nodes arises. Residual nodes prevented with re-clustering the nodes with the firefly algorithm. In this implementation uses five clusters where the data sending is happening form all nodes with one node at a time. The strategy is repeated with the firefly algorithm for the calculation of cluster on the base of brightness. Simulation parameters shown in Table 1.

There are some assumptions for simulation 1. Every node is considered as firefly and every node consist of its own battery. 2. All nodes have same energy during initialization phase and nodes deployed randomly in search space. 3. When nodes move and during transmission energy consumed.

Table 1: Network Parameters

Parameter	Value
Network Coverage	100m x 150m
BS Location	50m,150m
N (Number of Nodes)	100
Initial Energy (E_0)	0.5 J/bit
E_{elec} (Energy required in radio Electronics)	50nJ/bit
E_{fs} (free space)	10pJ/bit/m2
E_{amp} (multipath fading)	0.0013PJ/bit/m4
d_o(Threshold distance)	87m
E_{DA} (Energy Aggregation Data)	5nJ/bit
Data Packet Size	4096 bits
Control packet size	200 bits

4.1 Results Interpretations:

Results are evaluated with simulation of LEACH protocol in which residual nodes arises due to coverage problem. In which colored nodes represent clusters and blank nodes represent residual nodes due to coverage problem as shown in Figure 5. In proposed hybrid approach LEACH protocol uses with usage of FFO for clustering. During reclustering residual nodes join nearest clusters on basis of distance calculation with firefly algorithm as in Figure 2. Residual nodes prevented with reclustering on basis of distance calculation as brightness feature calculation of light intensity.

4.2 Performance Analysis

Various parameters are analyzed and compared with existing and new approach like energy consumption, number of dead nodes, Network Lifetime.

Energy Consumption

Energy Consumption of node measured on basis of transmission. The energy comparison also shows the energy consumed comparison between LEACH, DT and FFA. FFA performs better consuming less energy because the cluster is now better so the energy consumed is less as shown in Figure 6. It can be calculated as E_p previous energy, E_c current energy, E_r residual energy $E_r = E_p - E_c$

Dead Nodes:

The number of dead nodes are compared with the LEACH, DT and FFA. FFA performs better in showing that less nodes are dead when compared with other algorithms. Number of dead nodes with respect to the rounds are shown in the below table3.

Network Lifetime

The life time of the network is improved by using Firefly algorithm to select the cluster head in wireless sensor network environment. When the Energy consumption is less and number of dead nodes are also less by using FFA in cluster head selection.

Table 7.7: Report on Dead nodes, Residual energy and Alive nodes in Wireless Sensor Networks

S.No	Number Of Rounds	Direct Transmission			LEACH			Firefly Algorithm		
		Dead Nodes	Residual Energy	Alive Nodes	Dead Nodes	Residual Energy	Alive Nodes	Dead Nodes	Residual Energy	Alive Nodes

1	1	0	49.84	100	0	49.96	100	0	49.96	100
2	50	0	41.77	100	0	48.22	100	0	48.41	100
3	100	0	34.02	100	0	46.53	100	0	46.93	100
4	200	16	19.19	84	0	43.17	100	0	43.82	100
5	300	43	11.65	57	0	39.81	100	0	40.79	100
6	400	59	7.44	40	0	36.46	100	0	37.63	100
7	500	67	4.74	33	0	33.09	100	0	34.59	100
8	600	73	2.66	27	0	29.74	100	0	31.54	100
9	700	82	1.40	18	0	26.38	100	0	28.52	100
10	800	90	0.61	10	0	23.05	100	0	25.45	100
11	900	95	0.26	5	0	19.70	100	0	22.42	100
12	1000	98	0.11	2	0	16.37	100	0	19.39	100
13	1100	99	0.07	1	3	13.09	97	0	16.31	100
14	1200	99	0.03	1	18	10.14	83	0	13.37	100

Graphical Representation of Results:

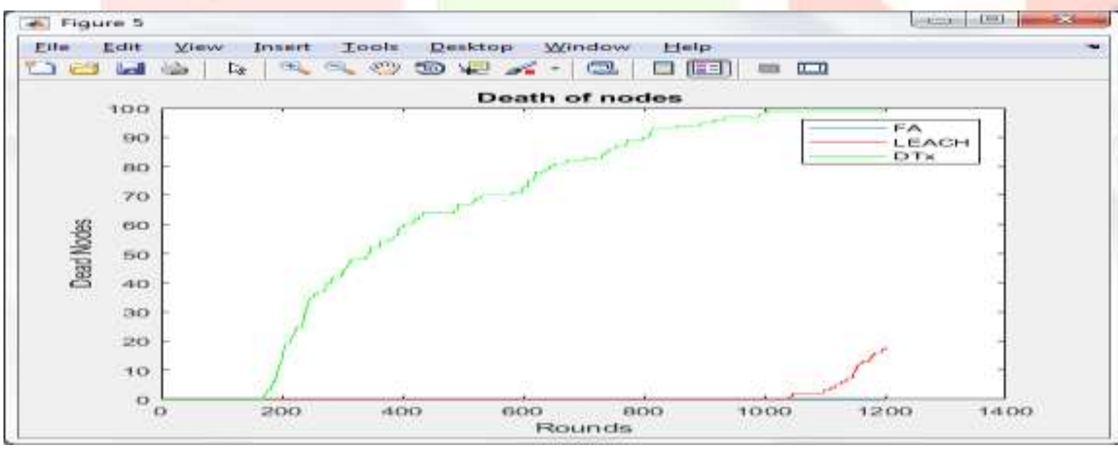

Fig.2 Report on Dead nodes

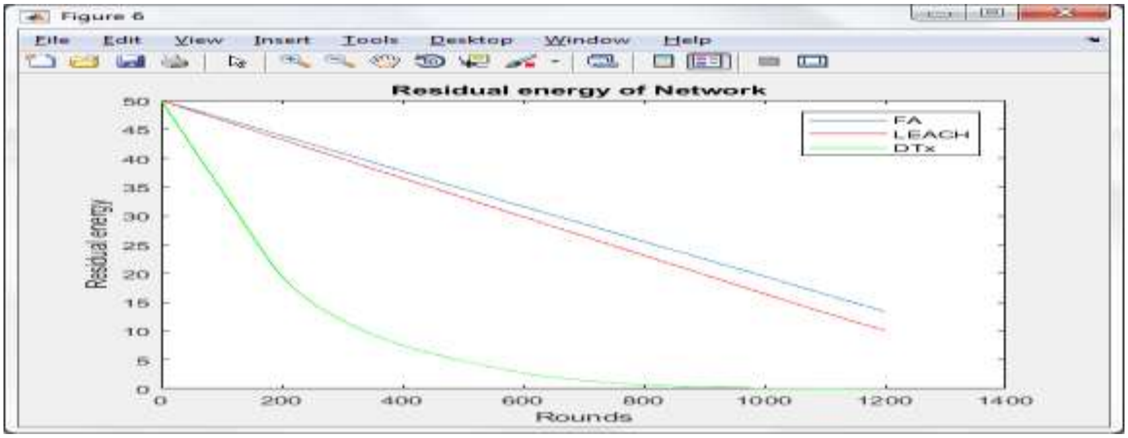

Fig.3 Report on Residual energy

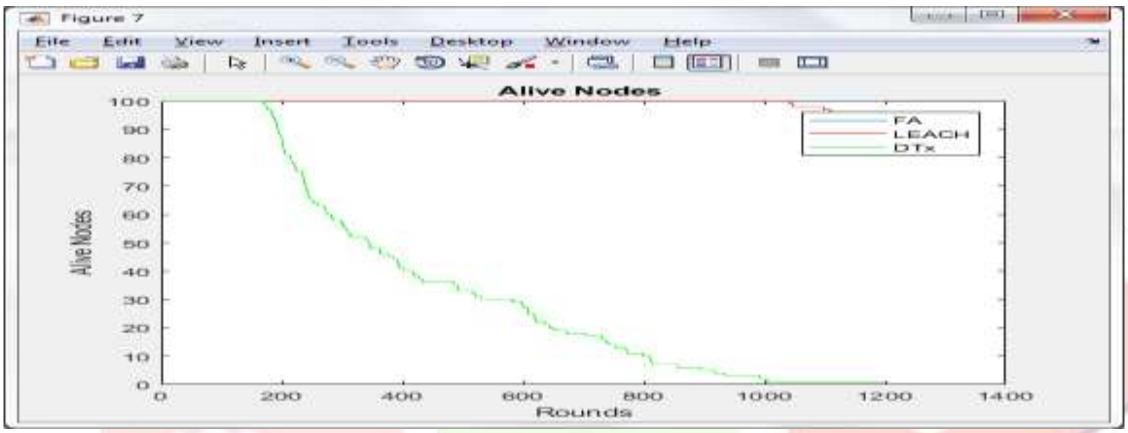

Fig.3 Report on Alive nodes

6. Conclusion.

To maximize the network life time optimal cluster head selection is important. Cluster Head's require more energy than all other nodes because they perform processing, sensing, communication and aggregation. In case, the cluster head dies ion earlier, then the entire network becomes useless; since the CH cannot communicate with Base station. To obtain optimal cluster head, CH should be elected based on residual energy of each and every node. Therefore energy efficiency is maximized & network lifetime is also prolonged.

In our project, in order to achieve energy efficiency a new meta-heuristic based cluster head selection process is used i.e. Firefly based cluster head selection algorithm. We evaluated proposed technique and compared with LEACH and Direct Transmission (DT). Our proposed technique perform better than these two clustering approaches. Proposed model can further improved by hybridizing these meta-heuristic algorithm. to achieve better results to optimize the energy utilization and to improve the life time of the network in wireless sensor networks.

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