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Genetic algorithm based area optimization with cluster head in wireless Heterogeneous networks.

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Abstract

In the WSN – Wireless Sensor Network, the limitations on the sensor's battery is the prime constraint for achieving optimum network performance. For selecting the CH – Cluster Head, many researchers have proposed several methods for optimization in the WSNs of homogeneous type. But for HWSN – Homogeneous WSN, there is still a huge scope is available for enhancing its capabilities. In this research work, GAOC – Genetic Algorithm based Optimization of Clustering protocol for area optimization is proposed for optimized selection of CH. This protocol uses the parameters like sink distance, density of nodes and residual energy for the fitness function. In addition, to solve the problems with hot-spots and to reduce the distance of communication between nodes and sinks, MS-GAOC Multiple-data Sinks based GAOC was presented. For the fair comparisons, experiments were conducted with MS-GAOC and the designed protocols. By using the results of simulation with respect to the parameters of performance like lifetime of network, period of the stability, dead nodes with respect to rounds, remaining network energy and the throughput of the network, it is inferred that GAOC and the MS-GAOC perform better than the existing protocols. The presented protocols are expected to play prime role in controlling hostile type of applications like detection of fire in the forests, early recognition of volcano eruptions and others.

Keywords: CH, GAOC, Heterogeneous network, HWSN, MS-GAOC, WSN.

1. Introduction

Wireless sensing technology has become a revolutionarily developing technological advancement [1] and [2]. WSN is defined as the network which interconnects several nodes that are operated by battery. These nodes have the ability to sense the physical quantities like moisture, temperature, vibrations, and others. They can store the data and perform processing of signals for communication through wireless media [3]. Based on the applications, these nodes are classified into four categories [4]:

- *Event dependent:* Sensors are activated when a particular event has been detected otherwise sensors were in the sleep mode.
- *Query dependent:* Sensors get initiated from the sink and activated when the query generated, otherwise they stay in the sleep mode.
- *Periodic measurements:* Dissemination of the data was done at regular intervals.
- *Based on tracking applications:* Here the nodes are the combinations all the above three.

WSNs have given enormous openings in several fields, from applications in the military domain to the applications in the agricultural field. It also plays significant role in the different domains like civil, automation of the houses, controlling industries, environmental, and others [5]. But, the huge capacities of WSNs are not utilized to maximum extent because of the power limitations on the nodes used for sensing. Several researchers concentrated on the efficient utilization of sensor node energy such that performance of network can be fulfilled [6]. The conventional methods of routing like minimum energy transfer and direct transmissions are not able to conserve the required energy in the nodes [7]. To solve this problem, concept of clustering was introduced in hierarchical routings, LEACH – Low Energy Adoptive Cluster Hierarchy [7]. This protocol with the single aim of conserving energy showed that it was better than the conventional methods in homogenous networks. In homogeneous networks, the energy level of all the nodes present contain same amount of energy, and have same capability of computation and sources coverage. Consequently, several protocols that are based on the LEACH concepts were presented that improved the performance of the network greatly. Though LEACH is a homogeneous method, the sensors in the network may not have the homogeneity due to the different factors of morphology, manufacturing variations, irregularity in the physical terrain, etc. [8]. When these nodes are used in the network, the homogeneity of the network will not be there be retained and the network becomes heterogeneous and the nodes become heterogeneous. There are many types of heterogeneity, out of which heterogeneity in energy is most important and is used popularly, because the batteries in the nodes are irreplaceable [9].

In cluster based protocol, the CH is selected for each cluster depending on some factors. Aggregation of the data has been done to eliminate redundancy in the data after all the data has been collected from all cluster nodes [10]. Subsequently the CH will have more drainage of energy when compared to other node members of the cluster. The data collected from the members of the cluster were then transferred to sink via single hop or via multi-hops in the network and then sent to the user through the internet resources [11].

Technically area optimization involves using minimal number of base stations to cover the given area. An effective and complete coverage of the area is required to have an optimised utilisation of the base station in the wireless communication [12].

2. Existing systems.

Several researchers proposed their research approaches to optimize the selection method of CH in homogeneous networks by using meta-heuristics techniques [13]. But in HWSN, the selection of the CH is done using few tactical-amendments that are based on the threshold values of nodes [10]. It is required to reduce the consumption of energy to optimize the selection CH. But, the selection of CH for energy effective routing is a NP – Non-deterministic Polynomial time hard issue. The CH selection can made optimized by using few meta-heuristics techniques that incorporate a small number of parameters to build fitness functions [14]. To perform this, meta-heuristics techniques are applicable to the features of grounds to provide optimized solutions.

Multitudinous optimizing routing approaches are designed for selecting the CH to assure the network reliability in the transfer of data [15]. GA – Genetic Algorithm [16], [17], [18], PSO – Particle Swarms Optimizing [19], [20], [21] and ABC – Artificial Bees Colony [22], [23], [24] are few important meta-heuristics approaches that are considered to optimize the selection of CH. In these methods, here we are using CH selection based on the GA, because it assures the continual enhancement of the solution towards the optimization and it is a robust in nature. In addition, it essentially concentrates on saving energy in the nodes.

Wireless radio in nodes is the critical energy consuming element which is used to communicate with the sink and other nodes in the network [25]. The power required for the transmission, directly decreases with the squared or of higher order of distance between the nodes and the sink or within the nodes. In the applications where ROI – Region of Interest contains large geographical area, the long distance data transfer between nodes causes decay in their energy and results in halting of the network functions. Thus, implementation of multi-hop transmissions becomes unavoidable which results in decay of energy in the relaying nodes. After data packets are transmitted over some time, the relaying nodes gets drained off their complete energy and leads to the connectionless zone, i.e., creation of hot spot is done

[26]. Even though several algorithms are presented in fixing the issue of hot spot by the intact of single sink, this issue is still a non-trivial one.

3. Proposed Methodology

For providing a solution to this issue, we are employing multiple sinks that are located outside ROI which causes nodes of CH to have data transmission in single hop to the closest sink. The proposed method is explained below in two models:

- System model and
- Energy model.

3.1 System Model

This model contains a BS – Base Station and N number of sensor nodes that situated uniformly in the coverage area to enhance the connectivity of network. The sub-sections and concealed details of the network are as given below:

- The complete network is static that contains sensors (nodes) and BSs.
- In the beginning all the nodes are provided with same amount of initial energy.
- BSs are provided with high energy computation capabilities and with no limitation of the energy utilization.
- PCH – Primary Cluster Head and SCH – Secondary Cluster Head are selected periodically based on the localization and coverage area.
- Energy of the nodes is optimized based on the distance of transmission.
- Wake-up and sleep concepts are introduced for the nodes in the network to minimize the consumption of energy.
- Both PCH and SCH are of multi-weighted to maintain varying levels of energies.
- Each node is provided with the ability to transfer its address to its neighboring nodes within the network.
- Both PCH and BS are located within transmission distance or range in network.

3.2 Energy Model

In the proposed system there are two types of power losses occur, viz., power loss in free space (d^2) and power loss due to multipath-fading (d^4). The channel model is selected based on the distance of transmission between source and sink. Free space channel model is selected if the distance is less than threshold (d_{th}) value else multipath-fading channel model is selected. The utilization of the energy depending on the distance parameter is computed by using the below equation (1):

$$E_{TX}(l,d) = \begin{cases} l \; x \; E_{energy} + l \; x \; E_{tm} \; x \; d^2, if \; d \leq d_{th} \\ l \; x \; E_{energy} + l \; x \; E_{am} \; x \; d^2, if \; d \leq d_{th} \end{cases} \tag{1}$$

where E_{energy} is the total circuit energy dissipated/bit, E_{tm} is the transmitter energy model and E_{am} is the amplifier energy model and d_{th} is threshold distance of network and is given below equation (2):

$$d_{th} = \sqrt{\frac{E_{tm}}{E_{am}}} \tag{2}$$

Sink energy utilization is given by, $E_{RX}(l) = l * E_{energy}$

3.3 Model of Energy Consumption

Model of energy consumption is shown in the Fig.1. The energy consumed by the node to transmit one bit data to CH is given as in equation (3),

$$E_{non-CH} = l * E_{energy} + l * E_{tm} {d^2}_{cn-CH} \tag{3}$$

where ${d^2}_{cn-CH}$ is the distance between child node and CH.

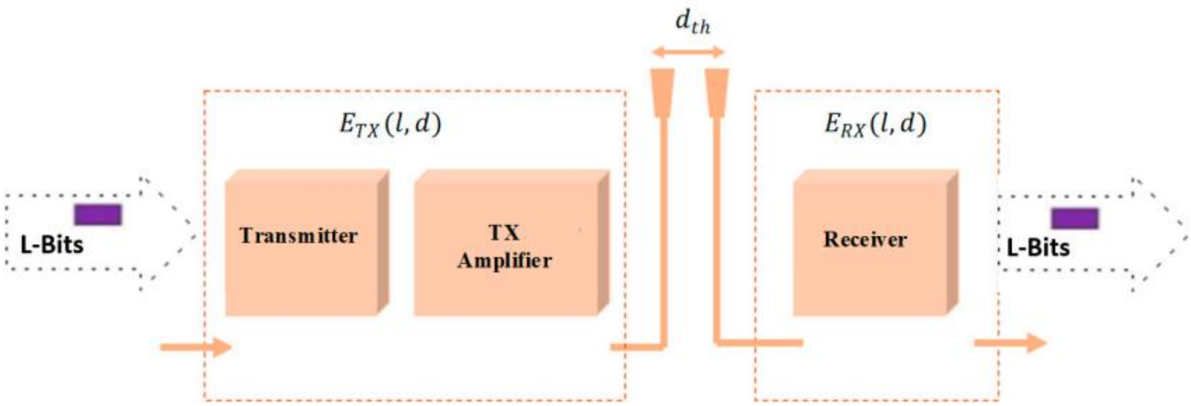

Fig.1: Model of energy consumption

Next, the energy consumed by CH is given as in equation (4),

$$E_{CH} = \left(l \left(\frac{n}{c} - 1 \right) * E_{energy} + \frac{n}{c} * E_{con} \right) + E_{RX}(l,d) + E_{TX}(l, d_{CH-BS}) \tag{4}$$

where, n indicates the number of the alive nodes present in network, c is number of clusters present in the network, E_{RX} is consumption of energy by the CH, and $d_{CH\text{-}BS}$ is the distance between BS and the CH.

Cluster Formation

Generally, BS sends hello packets to all the groups for selecting the CH. The nodes in the group send reply packets in response to the hello packet. The node that has minimum cost of communication and with the proper localization is selected as the CH. Next, the CH transmits hello packets to all the nodes in the network to select the CNs – child nodes [27][28].

Data Collection

In the data collection, the cluster CNs sends the data to their CH using a pre-determined time slot. This data contains information regarding the address of node and the node's initial energy. This data is required to get CHs for the next round. Data aggregation is done for the elimination of duplicate and repeated data. Finally, the CH sends data to its BS along with the CN's general data [29] [30][31][32].

4. Results and Discussion

Simulation Environment

For employing MWCSGA – Multi Weight Chicken Swarm based Genetic Algorithm experiments were conducted and NS-2 Network Simulator-2 tool is used for simulation purpose to evaluate the performance of the proposed protocol. The other techniques used for evaluating the performance of the network are CSOGA, MW-LEACH and GA-LEACH. The simulation was carried out rigorously for many times in different scenarios and in a cost efficient manner. The NS2 supports two languages, one is the front-end of the TCL and other is the back-end of C++. NAM – Network Animator performs the visualization of the output, i.e., the implementation of the nodes in the network at real-time. Similarly, trace files are utilized for the evaluation of the performance using the parameters of simulation and are given in the Table-1. The parameters computed are consumption of energy, efficiency of the energy, delay for end-to-end link, dropping of the packets, ratio of delivery of packets and the throughput.

Table 1. Different parameters of proposed model considered for simulation.

Parameters	Values
Simulator	NS-234

Simulation Period	100 ms
Coverage Area	1000 x 1000
No of Nodes	100
Initial Energy	0.5J
E_{DA}	5nJ /bit /signal
d_0	87m
Packet Size	4000 bits
E_{energy}	50nJ / bit
Free space (E_{tm})	10pJ /bit /m^2
Multi-path (E_{am})	0.00013 pJ /bit/m^4
Percentage of CHs	0.05

4.1 Calculation of Energy Efficiency

The efficiency of the energy is the residual energy after the transmission of the data over network. Fig.2 gives the comparison of efficiency of energy performance for different protocols like CSOGA, GA-LEACH, MWCSGA and MW-LEACH. For this case the simulations was conducted by considering 100 numbers of nodes. The performance of the energy efficiency of MWCSGA technique is 79.320% and is the highest when compared to all other methods considered. The CSOGA, GA-LEACH, and MW-LEACH approaches give the value of efficiency of the energy as 71.340%, 57.110% and 65.380% respectively. Thus, the analysis shows that MWCSGA's performance is better in comparison with others.

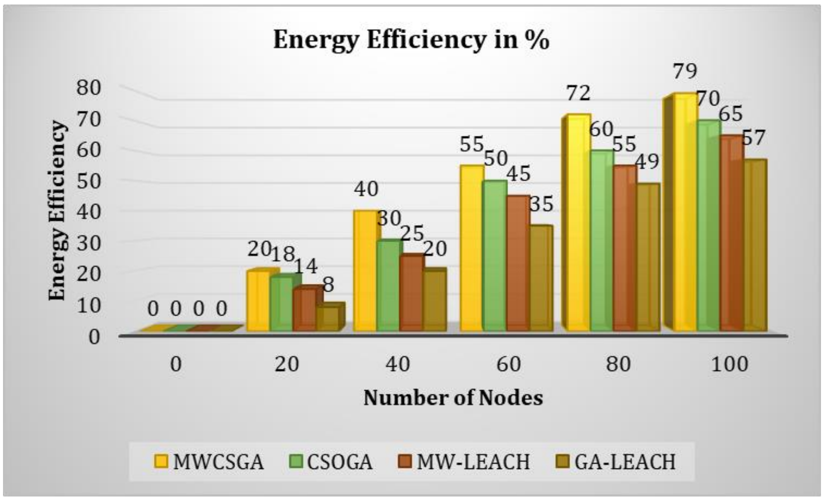

Fig.2: Plot of Energy efficiency vs number of nodes

4.2 Calculation of End-to-End Delay

End-to-end delay is the total time delay of network. Fig.3 gives the comparison of efficiency of energy performance for different protocols like CSOGA, GA-LEACH, MWCSGA and MW-LEACH. For this case the simulations was conducted by considering 100 numbers of nodes. The performance of the energy efficiency of MWCSGA technique is 99.860ms and is the minimum when compared to all other methods considered. The CSOGA, GA-LEACH, and MW-LEACH approaches give the value of end-to-end delay as 157.36ms, 275.12ms, and 233.35ms respectively. Thus, the analysis shows that MWCSGA's generates least time delay in comparison with the other protocols.

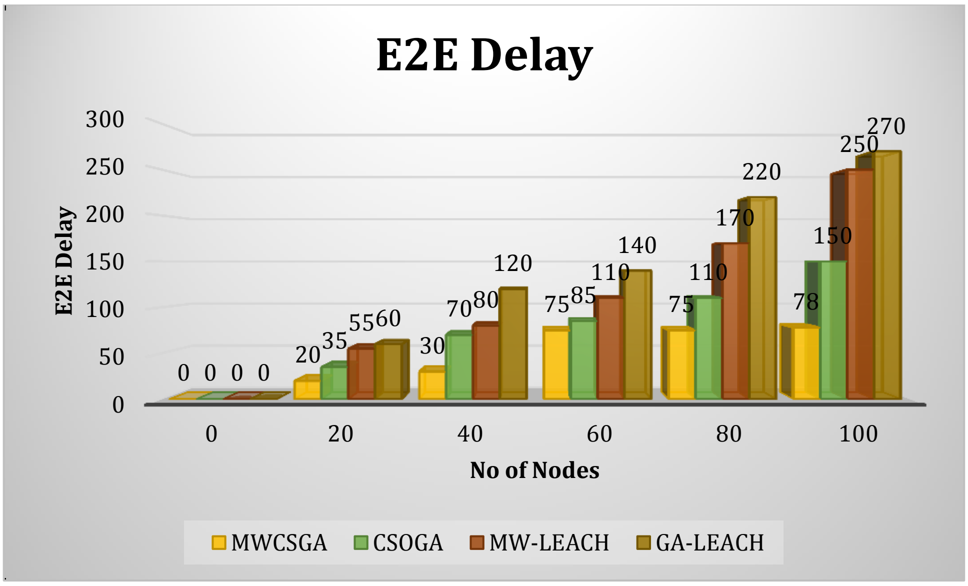

Fig.3: Plot of End-to-end delay vs number of nodes

4.3 Calculation of Packet drops

The calculation of the packet drops is done by the formula,

Packet drops = number of packet sent – number of the packets received.

Fig.4 gives the comparison of performance packet drops for different protocols like CSOGA, GA-LEACH, MWCSGA and MW-LEACH. For this case the simulations was conducted by considering 100 numbers of nodes. The performance of the packet drop of MWCSGA technique is 153 and is the minimum when compared to all other methods considered. The CSOGA, GA-LEACH, and MW-LEACH approaches give the packet drops as 330 packets, 650 packets, and 526 packets respectively. Thus, the analysis shows that MWCSGA's generates least packet drops in comparison with the other protocols.

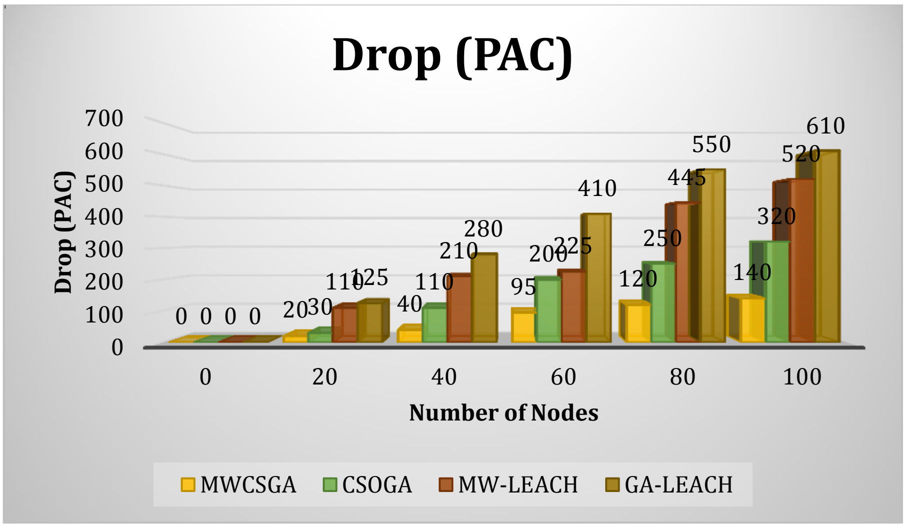

Fig.4: Plot of packet drops vs number of nodes

4.4 Calculation of throughput of the Network

Throughput of the network is the maximum number of packets received in a particular period of time. Fig.5 gives the comparison of network throughput performance for different protocols like CSOGA, GA-LEACH, MWCSGA and MW-LEACH. For this case the simulations was conducted by considering 100 numbers of nodes. The performance of the energy efficiency of MWCSGA technique is 679.82Kbps and is the maximum when compared to all other methods considered. The CSOGA, GA-LEACH, and MW-LEACH approaches give the value of throughput as 551.350 Kbps, 190.530 Kbps, and 354.370 Kbps respectively. Thus, the analysis shows that MWCSGA's gives highest value of throughput and perform better in comparison with the other protocols.

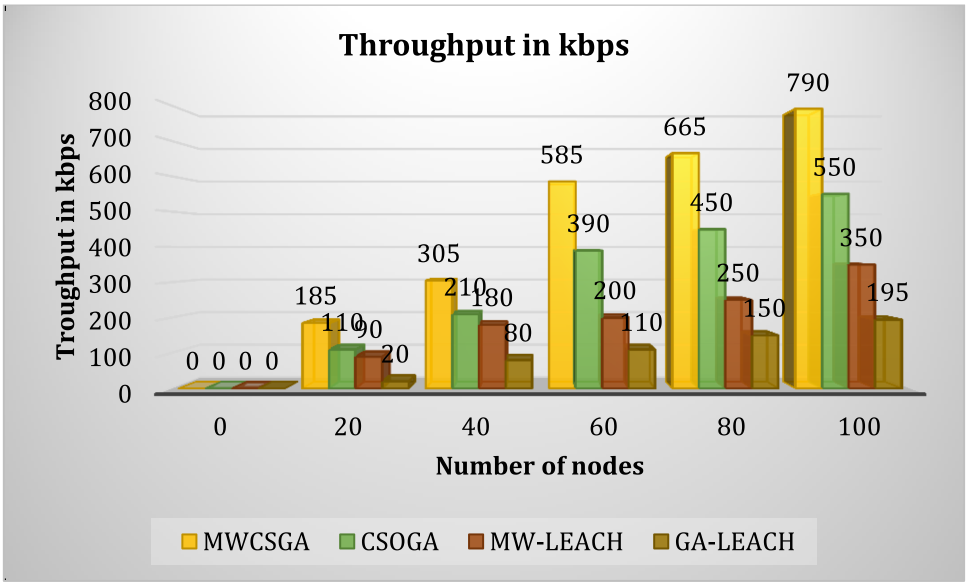

Figure-5: Throughput calculation

5. Conclusion

In the recent days, the WSNs have been implemented in various applications, but always there is a problem with the consumption of energy. To enhance the life time of network, improvement of efficient utilization of energy is majorly focused in this research work. In this, we have proposed MWCSGA – Multi Weight Chicken Swarm based Genetic Algorithm to enhance the energy efficiency for data transmissions in network. To benchmark the proposed system, it is compared with the some other approaches like CSOGA, GA-LEACH, and MW-LEACH. The results of the simulation experiments conducted used the parameters like efficiency of the energy, end-to-end delay, ratio of packet delivery and throughput of the network indicated that the proposed method performs better when compared with the other existing methods which are considered. When the proposed method is applied to the large-scale network based applications, there is a chance of getting delay in the communication. For this we have made the plan to apply the normalization to the network model in future and we can make the comparisons with the more recent techniques in the current domain such as P-SEP and N-SEP.

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