AI Methods for Routing in Wireless Sensor Networks

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1. Introduction

Wireless Sensor Networks (WSNs) is an infrastructure-less and self-configured wireless network to monitor environmental or physical conditions like sound, temperature, pressure, vibration and motion. The base station acts as an interface between the network and the user. Generally, a Wireless Sensor Network consists of hundreds of thousands of nodes. In WSN, Routing is required to send data between the base station and sensor nodes. During the routing of Wireless Sensor Networks, there can be multiple challenges that occur due to network topology, undesirable deployment conditions, network failure etc and it mainly causes lower network lifetime with more energy consumption. (Matin et al, 2012)

Keywords – WSN, Routing Protocol, A* search, GA, sensor nodes, LEACH.

In this essay, I am going to talk about the challenges faced during routing of Wireless Sensor Networks and to solve this issue we are going to use two popular algorithms A* Search and Evolutionary algorithm. A star algorithm is used to find the shortest path from source to the destination whereas the Evolutionary Algorithm uses the mechanism which is inspired by nature and finds a solution through techniques that emulate behaviours of living organisms. For the literature search, I mostly used the databases such as ACM Digital library where I found articles on WSN and routing protocols, in IEEE Xplore ebooks I found papers on A* search algorithms for WSN and Evolutionary algorithm for WSN and a few papers about routing in WSN and I also found some information about the explanation of Wireless Sensor Networks and definitions of few important terms used in the essay from journal databases such as intechopen and ijarcce. I have also gone through citations of the scientific papers to find another paper that is relevant for this essay. I have used keywords to search in the database to get relevant content for this essay and I compared all the sources and decided to go for papers, articles and journals mainly because they were to the point, easy to understand and had more citations since a lot of research has taken place to solve routing problems in WSN using A* search and Evolutionary algorithm.

2. Routing in Wireless Sensor Networks

The selection of a path for traffic between or across networks is called routing. Routing is carried out on types of networks such as circuit-switched networks like PSTN- public switched telephone networks and computer networks like the Internet. Wireless Sensor Network routing depending on the structure of the network can be classified into flat-based routing, hierarchical-based routing, and location-based routing.

- In flat-based routing, every node has an equal role or functionality.
- In hierarchical-based routing, nodes have a distinct role in the network.
- In location-based routing, the sensor nodes positions are utilized for routing data in the network.

Sensors are used for measuring the ambient conditions in the environment and transforming them into signals which can be used to get information about the phenomenon located in the surroundings of the sensors. These sensors are networked for desirable applications that need an unattended operation. Therefore, it can be used for Wireless Sensor Network (WSN). Wireless Sensor Network comprises thousands of such sensor nodes which can communicate with external Base Station (BS) or among themselves. Large quantities of such sensors can provide communication over larger geographical areas with greater accuracy. (Al-Karaki et al, 2004)

Problems in routing cause lower network lifetime with higher energy consumption and other issues for routing are node deployment, scalability, connectivity coverage, security, etc. While routing Wireless Sensor Network there are a few challenges and design issues as follows:

- **Node Deployment:** In Wireless Sensor Network, the node deployment is application-specific, and it is either randomized or manual. In randomized deployment, the sensor nodes are distributed randomly and that makes an ad-hoc routing framework but in manual deployment, the sensors are placed, and all the data is routed through desirable paths. The randomized deployment results in varied distribution of nodes which makes *clustering* necessary to allow connectivity and energy-efficient network operations. Due to the constraints in bandwidth and energy restrictions, the inter-sensors are usually on short transmission range and that results in a route with multiple wireless hops.

- **Energy consumption without accuracy loss:** Restricted supply of energy to perform transmission and computation is used up by sensor nodes therefore it is vital to save energy. (Heinzelman et al,2000) During multihop, the sensor nodes in Wireless Sensor Network can malfunction due to power failure causing topological difference and to solve this issue rerouting of packets and reorganization of the network is necessary.

- **Node/link heterogeneity:** All sensor nodes are expected to be homogeneous which means that it has an equal capability regarding computation, communication, and power. A heterogeneous set of sensors will create a lot of technical issues in terms of data routing. For example, a Wireless Sensor Network application might require a variety of sensors for measuring temperature, pressure, and humidity etc and these sensors will be deployed independently, or various functions will be included in the same sensor nodes. (Al-Karaki et al, 2004)

- **Scalability:** The scale of deployed sensors can be in hundreds or thousands or more. The routing scheme should work with large scale sensor nodes and sensor network routing protocols should be scalable enough regarding the events in the surroundings.

- **Fault acceptance:** The sensor's node could miscarry or be crowded due to less power or environmental intervention. If a variety of nodes stops working, then Medium Access Control (MAC) and the routing protocols controls the situation and find a way to collect data at the Base stations.

- **Data Broadcasting Techniques:** In Wireless Sensor Network, it is influenced by the time criticality of the data. The broadcasting of the data is categorized as period driven, occurrence driven, or query-driven or a combination of these three.

- **Data accumulation:** Wireless Sensor Network may have data that is redundant. Data accumulation is an amalgamation of data from non-similar sources that agree to accumulation. To route protocols, the methods used are to gain high energy effectiveness, data transfer optimization and processing of signals.

- **Path preservation:** During multipath routing, the paths used from source to target should be preserved occasionally to attain high data trustworthiness and load balance among various paths. This helps in finding alternative paths if the path used previously during transmission is wrecked. The target node decides which path to preserve, or which is set up in the application.

- **Quality of service:** In some applications, for data to be practical the data must be distributed within a convinced period from the instant it has been sensed or it will be impractical. Nevertheless, preservation of energy (which is related to network span) is more important than the quality of data referred to. (Randhawa S.,2004)

3. A* search for Routing in Wireless Sensor Networks

A-Star algorithm is used to search for the best path and to traverse graph efficiently. A- Star search algorithm performs better than Dijkstra's Algorithm regarding time. A-Star uses heuristics for decision making. It is a best-first search algorithm that finds the optimal path from source to destination. (Hart et al,1968)

3.1. A-Star algorithm for energy efficient routing in WSN (Rana. K. & Zaveri M., 2011)

In this section, the A-Star algorithm is used to search for optimal routes from source to destination so that the overall life of the network is extended. A pre-defined energy level (Level 1) is used for sensor nodes so that they don't participate in routing if the residual energy level is below level 1 and better paths are available. A-Star algorithm creates a tree structure to search for optimal routes from a given source to a destination. Tree node is explored based on its $f(n)$ value, which the algorithm uses to search for an optimal path, where $f(n) = g(n) + h(n)$. In this approach, an additional parameter is used to calculate the strength of the route which continuously keep track of current energy levels in the sensor node. This new parameter, $l(n)$ is the path cost count of the weak node with less energy i.e., it keeps a counter of the number of nodes in the current path below Level1 of energy level. Therefore, the Estimated cost function $f(n)$ is given by:

$$f(n) = (g(n) + h(n), l(n))$$

To calculate the estimated cost function *f(n),* for node n with parent node *p*, the intermediate node *l(n)* counts the total number of nodes that are on the route and are below the threshold level of energy level1 as pre-defined. The residual energy of node *n* is observed and if it is less than the threshold energy level, then *l(n)* will be *l(p) + Incremental_factor*. To assign the incremental factor we take, the proportionate value to residual energy left in the sensor node. (Rana. K. & Zaveri M., 2011)

The Pseudo Code for Proposed Efficient Routing Algorithm:

```
Input   : Sensor Network
Output  :  Life of Sensor Network in terms of rounds
 1. BEGIN
 2. InitilizeNetwork()
 3. EstimateDistance() // finds distance to the BS
 4. WHILE NOT END_ASTAR() // N-of-N metric [11]
 5.     InitializeSolArray() // initialize solution
                //array to store routing schedule
 6.     FOR each node i in the Network DO
 7.       CreateTree (i)   //using A-Star algorithm
 8.       PrepareSolArray() //prepare routing schedule
 9.     END FOR
 10.    BroadcastSolution()  // BS broadcasts routing
                             //schedule
 11.    UpdateEnergy()  //Energy update for relay nodes
 12.    CountRound = CountRound + 1  //count n/w life
 13. END WHILE
 14. PRINT CountRound  //print n/w lifetime in
 15. END
```

In the pseudo-code, estimation of the distance from each node to the Base Station can be carried out with the above-mentioned method and this distance is crucial to calculate the energy consumption between two nodes. To obtain the heuristic function, h(n) this estimated distance is used. Base Station updates the node's residual energy after the routing schedule is prepared. The CountRound variable is used to hold the value of several rounds that measures network lifetime.

For this method, we took the first order radio model for communication energy dissipation (Heinzelman et al,2000).

$$E_{T_i}(b_{t_i}, d_{i,j}) = \alpha_2 b_{t_i} + \beta b_{t_i} + d_{i,j}{}^m$$

Where $d_{i,j}$ is the Euclidian distance between two nodes i and j, which varies from 25 to 40 meters. $\alpha_2$is coefficient of transmitting energy, β is amplifier coefficient, b_{t_i} is the amount of data to transmit between two nodes and m is path loss exponent, 2≤m≤4. $E_{T_i}$is the total transmit energy dissipated. The receive energy is given as:

$$E_{R_i}(b_{r_i}) = \alpha_1 b_{r_i}$$

The total energy dissipated by a node i is given by $E_i = E_{T_i} + E_{R_i}$.

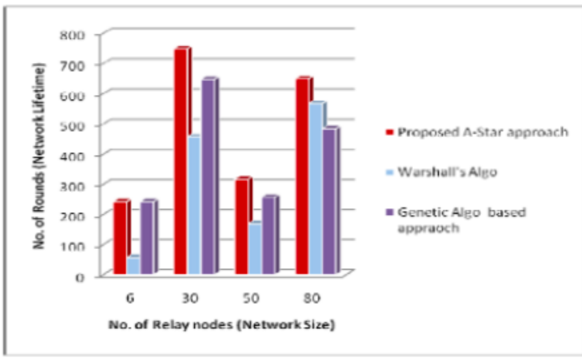


Figure 1. Comparison of A-Star based, GA based approach and Warshall's algorithm.

Figure 1 shows the comparison of the A-star based approach with GA based approach and Warshall's algorithm. It is observed from the figure that using the A-Star algorithm, the lifetime of the network is extended. In most cases, it is extended about 15% than the GA based algorithm and more than 40% than Warshall's algorithm. (Rana. K. & Zaveri M., 2011)

3.2. Evaluation function effectiveness in WSN routing using A-Star algorithm

(Septiana et al,2016)
In this method, the evaluation function based on heuristic value is compared so that the effect of variations on the results of path searching would be notified. The A-star algorithm is proposed, where the actual cost and estimated cost calculations with heuristic function to find the shortest path is used. The advantage of using the A-star algorithm are as follows:

1. Efficient in path searching with the use of the evaluation function which determines path optimization.
2. Simplified the complexity of calculation and maximizes the search process.
3. The implementation is simple and easy to understand.

The path of cost taken at A-STAR uses a cost function referred to evaluation function is given below:

$$f_1(n) = g(n) + h(n) \qquad (1)$$

The heuristic function of A-star uses a parameter of LQI (Link Quality Indicator) which determines the path selection with the highest energy efficiency value, to successfully transmit data packages on Wireless Sensor Network routing and to determine the success of the package, value of RSSI parameter is considered which is the signal strength between nodes conducting communication so that the calculation efficiency is achieved. LQI is calculated by:

$$RSSI = A - 10n_P \log d, \qquad n_P = 2 \qquad (2)$$

$$RSSI = (P_t - PL) - 20 \log d \qquad (3)$$

$$LQI = \frac{RSSI}{RSSI_{min}} \qquad (4)$$

P_t is transmitting power. PL represents path loss node value with a 1m reference distance. $RSSI_{min}$ value is -97 dBm which is the worst RSSI value for data package transmission. (Elhabyan et al, 2015) or (Srinivasan et al,2006) or (Zheng et al,2011)

The evaluation function of A-Star was calculated to obtain f(n). Values of g(n) and h(n) are as follows:
g(n) = LQI of the parent nodes(P) to its child(C)

$$g(n) = \frac{RSSI_P \;\; to \;\; c}{RSSI_{min}} \qquad (5)$$

h(n) = LQI of the child nodes to the target nodes

$$h(n) = \frac{RSSI_C \;\; to \;\; c}{RSSI_{min}} \qquad (6)$$

The performance of the proposed evaluation value is done by adding a review on heuristic value with the use of the 1st heuristic value as the parent of the next values and the parent will have child heuristic values of its nearest neighbour. The addition of the value will lead to optimization of the achieved path. (Liu X & Gong D,2011) The addition of heuristic value has two phases:

1. Considering the LQI value of the child (C) to its grandchild (GC) nodes. The equation is as follows:

   $$f_2(n) = g(n) + h(n) + h'(n) \qquad (7)$$

   $$h'(n) = \frac{RSSI_C \quad to \quad GC}{RSSI_{min}} \qquad (8)$$

   Where, h'(n) is the LQI of the child nodes to its child nodes.

2. Considering the LQI value of the grandchild nodes (GC) with respect to the target and summing it to the LQI value of the neighbouring nodes to the destination node. The equation is as follows:

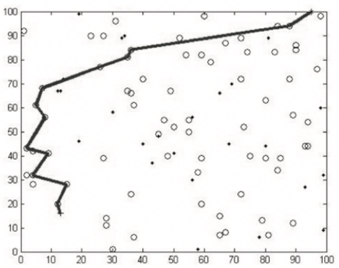
$$f_3(n) = g(n) + h(n) + h'(n) + h''(n) \quad (9)$$

$$h''(n) = \frac{RSSI_{GC} \quad to \quad target}{RSSI_{min}} \quad (10)$$

Where, h’’(n): = LQI of the grandchild nodes to target node. (Septiana et al,2016)

In the simulation of the experiment of Wireless Sensor Network routing using the A-star algorithm with evaluation function variation, the data used are the nodes of Wireless Sensor Network on a 100x100 field. The placement of the nodes is on a random and statical basis. A few important parameters in the static feature are the effect of precision and environmental sensitivity (Rahadian et al, 2015), this experiment is done with the variable number of active nodes. Tests are done on a similar number of nodes i.e., 100 nodes, but the difference in each experiment is the number of active nodes. The first experiment activates the 25 nodes, the second experiment activates 50 nodes while the third activates 75 nodes and further 100 nodes are activated which are considered as worthy of being a routing component. The three evaluation functions are tested in the three variations node and the output is the value of the hop count from the initial node to the destination node and the computation time.

Visually the test shows that each evaluation function has different paths, and the results are shown in Fig. 2., Fig. 3. and Fig. 4.



ig. 2. Path formed using the initial A-star

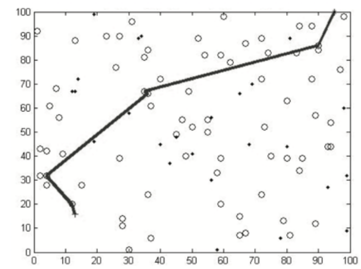


Fig. 3. Path formed using two heuristic functions

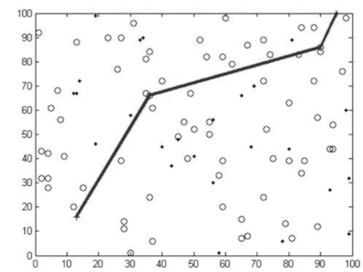


Fig. 4. Path formed using three heuristic functions

The simulation results are shown by the three figures above which shows that for each evaluation function, the paths formed are distinct. The higher the variety of heuristic values (which is used in the evaluation function), the lesser the hop count of the source node to destination node so a shorter path is formed. The calculated results of the number of hop count of each node to reach the destination point and the computation time to make a path as shown in table 1 below.

f(n)	Number of node	Hop count	Time (s)
f1(n)	25	9	0.046488
	50	12	0.060223
	75	14	0.095441
	100	18	0.11834
f2(n)	25	8	0.17146
	50	7	0.41227
	75	7	0.85725
	100	6	1.7988
f3(n)	25	4	0.15649
	50	4	0.44926
	75	4	0.78476
	100	3	0.86136

Table 1: Simulation Results

The value of f1(n) is the result of the evaluation function of the initial A-star whereas f2(n) shows the result of the evaluation function with the addition of one heuristic function while f3(n) conveys the result of the sum of two heuristic function. The above table shows the smallest hop count value is on the third evaluation function, f3(n).

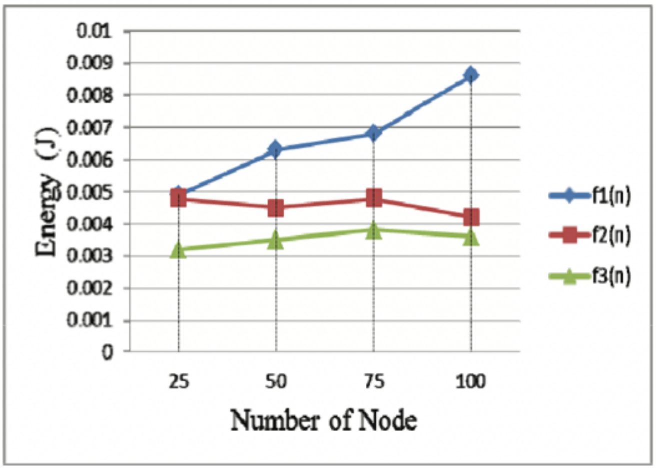


Fig. 5. Comparison of the effect of evaluation function effectiveness on the amount of energy consumption

The effect of adding heuristic function on the amount of energy consumption is shown above and f3(n) has a lower energy consumption among the other evaluation function. Therefore, the experiment proves that the effective evaluation function will enhance the process of routing in a Wireless Sensor Network. It is more effective and efficient. When there is more than one heuristic function it is the most effective evaluation function. It produces a smaller hop count and lowers energy consumption. (Septiana et al,2016)

3.3. More A* search algorithm for routing in WSN

There are a few other A* search algorithm-based approaches in Wireless Sensor Network such as:

- Ali Ghaffari proposed an energy-efficient routing protocol called EERP for Wireless Sensor Network routing using the A* search algorithm. EERP improves the network lifetime by moving the data packets through the shortest optimal path which was discovered regards to maximizing residual energy of the next hop sensor node, buffer occupancy, high link quality and minimum hop counts. The simulated results showed that EERP improves lifetime in contrast to A star and fuzzy logic(A&F) protocol. (Ghaffari A, 2014)
- Mostafa E, A.Ibrahim, Alaa E and S.Ahmed proposed an energy saving routing protocol for Wireless Sensor Network which considers the energy level of sensor nodes and the distance from the nodes to the base station to determine the best optimal route. It also uses the inherent complementarity of clustering techniques. This procedure exploits data aggregation to improve the utilization of energy and to lower the communication costs. To decide the best route between the node and base station an integration of ant colony optimization and A* is done and finally, the performance is compared to the other existing protocol, the results show that it outperforms them in terms of network lifetime, total energy consumption, stability period and goodput. (Ibrahim M. et al, 2021)

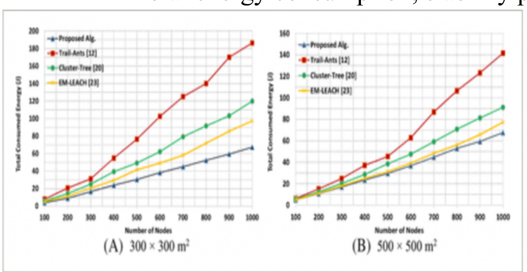


Fig. 6. Total consumed energy vs number of nodes

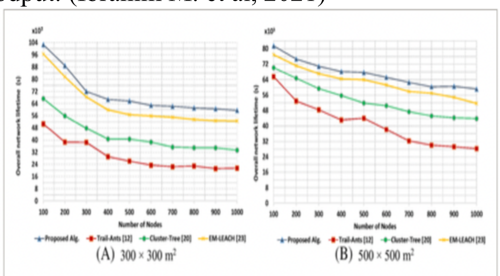


Fig. 7. Network lifetime vs number of nodes

- Yali Yuan, Caihong Li, Yi Yang, Xiangliang Zhang, and Lian Li proposed a new method for routing WSN to extend the network lifetime by combining a clustering algorithm, a fuzzy approach and an A-star method. Initially, WSNs are segregated into clusters using SEP (Stable Election Protocol) method and then the combined methods of fuzzy inference and A-star algorithms are used, taking factors such as remaining power, minimum hops, and traffic numbers of nodes into account. The simulated result shows that the method has significant effect in terms of balancing energy consumptions as well as increasing the network lifetime by comparing the performance of A-star and fuzzy approach (AF), cluster and fuzzy method (CF), cluster and A star method (CA), A star method and SEP algorithm under similar routing criteria. (Al Shawi et al, 2012)

4. Evolutionary Algorithm for Routing in Wireless Sensor Networks

Evolutionary Algorithms is a class of randomized heuristics inspired by natural evolution. (Thomas Jansen, 2013) Optimization is performed using evolutionary algorithms (EAs) and they are dynamic as they evolve over time and their main characteristics are:

1. **Population-Based:** Evolutionary algorithms are used to optimize a process where the current solutions are bad to generate a better solution that are new. The set of current solutions from which a new solution is generated is known as population.
2. **Fitness-Oriented:** When there are several solutions, to find the best solution a fitness value is observed on each solution calculated from the fitness function.
3. **Variation-Driven:** If there is no acceptable solution in the current set of population according to the fitness function calculated from each individual, we have to generate a new better solution.
   (Gad. A.,2018)

The Genetic algorithm is a random based classical evolutionary algorithm and is derived from Darwin's theory of evolution. It has 4 stages called initialization, selection, mutation, and crossover.

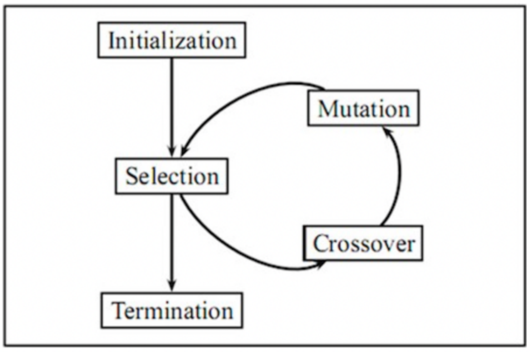


Fig.8. Process of Genetic Algorithm

- **Initialization:** At first, the Creation of population is done during this phase
- **Selection:** Fitness goal is calculated and the selection of the top performing subset of individuals is done to continue for the next step.
- **Mutation:** We Create a new population by mutating specific individuals.
- **Crossover:** And in the last step we create new individuals by the crossover between two or more entities from the current population.

This is continuously running until a stop criterion is met. (Mandelbaum et al, 2021)

4.1. Hierarchical Routing Protocol based on Evolutionary Algorithms for WSN

(Huruialâ P.et al,2010)

Wireless Sensor Network comprises many small sensors which are characterized by limited energy resources and processing power. To use its processing power at maximum it is important to have an optimal network. This method proposes and analyzes the efficiency of a hierarchical routing protocol that extends the life of the network and use its maximum processing power. We must analyze the efficiency of a hierarchical routing protocol to extend the life of the network by reducing energy consumption and latency by selecting the best nodes to become cluster-heads. Minimization is done with a multi-object genetic algorithm executed at the central base station and then further sent to the network nodes. The simulation is done in NS-2 where implementation of LEACH protocol already exists. (Huruialâ P.et al,2010)

LEACH is the first and most popular hierarchical routing protocol in WSN. It has low latency and is energy efficient. The nodes are organized into three hierarchical levels: nodes that collect data, level 1 cluster and a level 2 cluster. At first, the data flow with the end nodes that will send data to the level 1 cluster, which will further send it to the level 2 cluster and all clusters will accumulate data before sending it further towards the base station. A modular approach is done during the deployment of the routing protocol where the base station calculates the best solutions for cluster-head position while the nodes will run the algorithm with a small footprint to make it energy efficient. Redundancy is provided at level 2 routes and the messages have fixed length which introduces the minimum information that is necessary for data transmission. To determine the location, we have made use of two probes that periodically emits a signal at network boot. By using RSSI, the distance to the probe is calculated and sent to the base station. The geometric configuration is shown in figure 7. (Huruialâ P.et al,2010)

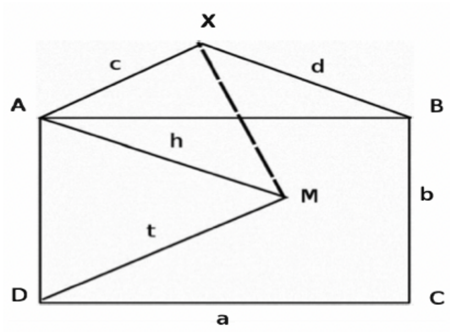


Fig. 9. Geometric configuration of node positioning

In the figure above, let us consider AX=c, BX= d, PM=h, DM=t, AB=a and BC=b. The formula to calculate the coordinates x, y and the distance is:

$$XM^2 = \frac{h}{a}(b^2 - c^2 - a^2)\sqrt{1 - \left[\frac{h^2-b^2-t^2}{2hb}\right]^2} + \frac{d}{b}(h^2 + b^2 - t^2)\sqrt{1 - \left[\frac{a^2+d^2-c^2}{2ad}\right]^2} + c^2 + h^2 \quad (11)$$

Following the principle of LEACH protocol, at the first stage, the cluster-heads are formed by the network to efficiently communicate the physical configuration to the base station. Since Wireless Sensor Network has thousands of nodes it consumes a lot of energy by communicating directly with the base station. Every node will be identified using the unique combination of “distance probe 1” and “distance probe 2” which will no longer need a new field with a node identifier.

Distance probe 1	Distance probe 2	Energetic level	Sensor type	...

Fig. 10. Message format for transmitting local coordinates to the BS

After transmitting the configuration and running the algorithm on the base station each node that isn’t selected to be cluster-head will join the closest CH and this determines the network lifetime and the energy level of every node. Network logical structure is shown in Fig. 11.

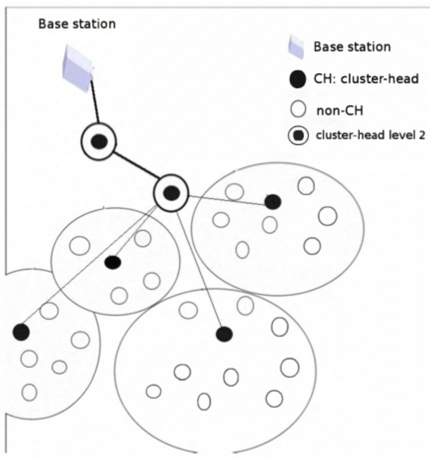


Fig. 11. Network logical structure

In this experiment, they have used a combination of the weighted sum of multiple objective functions to make them into a single scalar objective function. It is represented in formula (12). The direction of the search is not fixed because the novelty of this algorithm is the weights which are not constant but randomly selected for each round of the procedure. (Lindsey S et al,2002)

$$f(x) = a_1.f_1(x) + a_2.f_2(x) + \cdots + a_n.f_n(x) \qquad (12)$$

Where, a_i is a non-negative random number in the closed interval [0 , 1].

The eligibility for applying mutation and chromosomes in the Genetic algorithm is done by chromosomes evaluation. Genetic information is encoded using fixed-length chromosomes with binary values of 0 and 1 but they can be encoded as strings or even with variable lengths. Each node is represented with 2 bits of data that takes the value 00 for normal node, 01 for level 1 cluster-head and 1 for level 2 cluster-head whereas combination 11 is not valid and appearance is eliminated within the chromosomes. To enhance WSN response time and increase the network life we minimize two aspects of routing: latency and energy. Fitness function in formula (13) is:

$$f(x) = a_1 . f_1(x) + a_2 . f_2(x) \qquad (13)$$

Minimizing latency leads to minimizing the travel time of data from end nodes to the base station. The shortest time will be achieved when the communication between nodes and base station is direct but consumes high power, so a fitness function is proposed as follows:

$$t = \frac{d}{v}, v = ct \qquad (14)$$

$$D = \sum_{k=1}^{n} d_k \qquad (15)$$

To minimize energy consumption, it involves finding solutions where nodes communicate information on distance as short and as little as possible. Since we want a uniform allocation of CH in network space, the result where cluster-heads are equable spread so that energy consumption is uniformly distributed in the network.
The formula (16) represents the amount of energy consumed to transfer a message to the base station.

$$E = \sum_{i=1}^{k} E_{T_{ij}} + k.E_R + n.E_{T_{ij}} \qquad (16)$$

Since it is hard to calculate the distance and power consumptions of each node in WSN and after research, they concluded that to find the best solution is that it is not necessary to calculate all possible combinations, but only those which meet the condition of being located in the triangle formed by the closest CH, in figure 11, ABCD rectangle. It has a smaller search space and implicitly decreases the workload on BS. For every node, we seek the closest CHs and calculate the distance only for those.

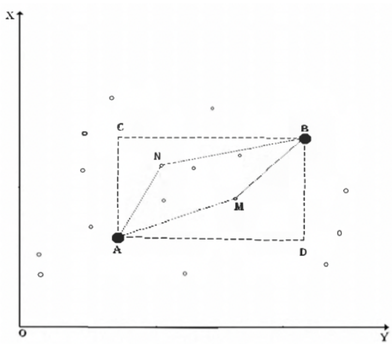


Fig. 12. Proposed Method for minimizing workload in fitness function evaluation.

The simulation of the protocol is tested in NS-2(Network Simulator) which already has LEACH implemented with those results as we compare. The modular approach is designing the protocol by dividing the simulation process in two stages. At first, where the best solution for cluster-head deployment is calculated and second is the actual routing process using the data from the first stage.
After simulation we obtained:

1. Random placements of nodes on the monitored surface.
2. Calculation of coordinates by each node and base station data transmission.
3. Determination of solutions by genetic algorithm and transmission of network.
4. There is routing activity, which is a process of data compression, BS data transmission, node scheduling, etc.
5. BS submits a new set of solutions at the end of each round.

We observed that the energy consumption is lower than LEACH's and about the same order of magnitude with methods that use evolutionary algorithms to minimize energy consumption and it also consumes less energy than PEGASIS due to network traffic. The latency is much better than for LEACH and PEGASIS because of the way both protocols choose to conserve energy without considering rapid information movement. (Huruialâ P.et al,2010)

4.2. More Evolutionary Algorithm for Routing in WSN (Nan G. & Li M., 2008)

4.2.1 Evolutionary algorithms for resource management in Wireless Sensor Network:

Resource management is the process to assign tasks to different processing elements from deciding the level of service quality required to scheduling the start times which determines the resource usage such as energy dissipation and communication bandwidth. To run the following tasks we should make full use of the resources of Wireless Sensor Networks to optimize the function of the total system.

- Qinru Qiu (Qinru Qiu,2006) discussed a distributed genetic algorithm for lifetime-aware resources management in WSN. Where GA was used to optimize resource management. The result was to allocate different detection methods for every sensor node such that the required detection probability is achieved while maximizing the network lifetime.
- Rahul Khanna (Rahul Khanna, 2006) Proposed a reduced-complexity genetic algorithm that was used to optimize the multi-hop sensor networks that generated an optimal number of sensor clusters with cluster heads which resulted in less power consumption of the system and increasing the sensor objectives. By assigning each node a 3-bit binary number, where each bit represents the type of cluster head for example 000 represents node inactive whereas 001 represents node cluster-head, 010 shows inter-cluster router and 100 depicts node as a sensor. The features are obtained for the model. Based on GA, we optimized the network to increase energy usage along with battery conservation by route optimization. (Nan G. & Li M., 2008)

4.2.2 Evolutionary algorithms for node positioning and target tracking:

Sensor nodes must be able to locate themselves in various environments. The data location is useful for a centralized server and the managing node to analyze the data that it is sensing. Query transmission and location-based routing are necessary as they can save a significant amount of energy by eliminating the requirement for route discovery (Hu L. & Evans D, 2004) and also improving the caching behaviour. Security is also enhanced by location awareness.

- Vincent Tam (Buczak A et al, 2001)(Tam V. et al,2006) proposed to use an evolutionary approach like a micro-genetic algorithm (MGA) to improve the precision of existing localization methods. Cross over operators and descend-based mutation is used and this resulted in reduced average estimation error.
- Anna L. Buczak (Buczak A et al, 2001) proposed a GA for the accuracy of target tracking and power usage optimization to perform self-organization of the sensor network which was capable to generate correspondent optimization problems as events and GA solves the problem through selecting sensors that result in accuracy of tracked positioning and low power optimization.(Nan G. & Li M., 2008)

4.2.3 Evolutionary algorithms for energy efficient routing in WSN:

The most concerning factor during routing of WSN is its usage of high energy, a significant part of communication in WSN is the systematic gathering of the sensed data to be sent to a data sink for further processing. The main challenge in such a data sink is to conserve the sensor's energy to maximize their lifetime.

- Sajid Hussain (Hussain S. et al,2006) presented a GA that affects the lifespan and quality of lifespan of a WSN by examining the change in fitness parameters used. The efficient routing technique can enhance the lifespan and improve the quality of the network by using several different parameters for the weights of the fitness functions and taking the quantitative measures of numbers on nodes that are closely spaced. For quality observation, the network is divided into 3 groups: 'Good', 'Average' and 'Poor'.(Nan G. & Li M., 2008)

4.2.4 Evolutionary algorithms for multi sensor fusion:

It is an evolving technology, concerning the problems of how to fuse data from many sensors to make an accurate assumption of the environment, power-efficient fusion will save the sensor's energy supply and increase its lifetime.

- Nithya Gnanapandithan proposed a Parallel Genetic Algorithm (Gnanapandithan et al, 2006) which optimizes the fusion rule as well as the local decision rules that are represented by binary encoding and account for the output of the fusion rule and the binary encoding method represents the local decision rule. There are N sensors that classify its measurement into L classes, each fusion rule accounts for L^N local decision outcomes. The optimization is performed over all possible local classification rules and also all the fusion rules to optimize this decentralized sensor network. (Nan G. & Li M., 2008)

5. Conclusion and Way Forward

Routing in Wireless Sensor Network is a new area of research with limited but fast-growing research results. In this essay, I talked about the routing in Wireless Sensor Networks and their classification based on the structure of the network into three categories: flat, hierarchical, and location-based routing protocols. The routing techniques have a common goal to increase the lifetime of the sensor network without compromising data delivery. Even though the routing technique looks promising there are a few challenges while routing the WSN which I discussed in detail. Furthermore, I discussed A* search based heuristic routing techniques and how they can be used to extend the lifetime of the Wireless Sensor Nodes and make it more efficient.

- At first, I discussed A* search for energy-efficient routing which was useful for data gathering without aggregation which are used in applications where all nodes send non-redundant data and are distinct. Besides the traditional algorithm, I have discussed path cost count that depend on a pre-defined level of minimum energy that helps the sensor node in energy efficiency and prolong its lifetime and stop from draining out which enhanced the overall performance of the Wireless Sensor Network.
- Secondly, I discussed evaluation function effectiveness in Wireless Sensor Network Routing using A* search algorithm in which we found the optimal path in Wireless Sensor Network Routing which is highly dependent on the heuristic functions. We were able to see an improvement in the evaluation function effectiveness by adding the heuristic functions while searching. When there is more than one effective heuristic function the evaluation function was more effective. This led to finding the optimal path during routing of Wireless Sensor Network and it could be visible by reducing the number of hop count and lowering the amount of energy consumption.
- Then we discussed in brief about various other A* search algorithm based approaches like introduction of an energy-efficient routing protocol called EERP which was able to improve the lifetime of the network, to determine the best optimal route we introduced an energy-saving routing protocol which considers the energy level of sensor nodes and distance from a node to the base station and finally I discussed a new method which extends the network lifetime by combining A star search, clustering algorithm and fuzzy logic in the network.

In the fourth section, I discussed the Evolutionary algorithms for routing in Wireless Sensor Networks. Evolutionary algorithms are a class of randomized heuristics inspired by natural evaluation. The genetic algorithm has four basic stages called initialization, selection, mutation and crossover. In this essay, I discussed the following kinds of Evolutionary algorithms for routing in Wireless Sensor Networks:

- At first, I discussed hierarchical routing protocol based on Evolutionary algorithms for Wireless Sensor Network which was used to enhance the lifetime of the network and response time in Wireless Sensor Network. The protocol was capable to route data and accomplishing some key constraints like energy consumption and low latency. It was difficult to obtain the best fitness function for the requirement but with other element taken into consideration, it yields better result. Elements such as distance between clusters and transmission number increase the life of the network.
- In this section, I discussed in brief, the various other Evolutionary Algorithm based approaches for routing in Wireless Sensor Networks such as Evolutionary algorithm for resource management in Wireless Sensor Network, Evolutionary algorithm for node positioning and target tracking, Evolutionary algorithm for energy efficient routing of WSN and Evolutionary algorithm for multi-sense fusion.

Wireless Sensor Network is an emerging field, and it has applications such as home automation, traffic control, smart battlefields, monitoring of environment and many more] and it has attracted many researchers in recent times. The main goal of routing in WSN is to send the data between sensor nodes and the base station, to establish communication. The problem in routing causes a decreased lifetime with higher energy consumption. So, the various routing protocol is discussed in this essay. (Sarkar A et al, 2016)

After working on this essay, the main routing problem is focused on network lifetime and higher energy consumption which I believe is the most important problem in the routing of W5SN. By designing a protocol that makes the sensor nodes and the network consume less energy leads to a better network lifetime since energy efficiency is increased and I believe the Genetic based algorithms yields better results in comparison to A-star based algorithms as the primary goal of A star is to find the optimal path but I believe the researchers from the evolutionary computation community is paying more attention and are constantly coming up with better solutions for the routing problems. The Evolutionary algorithm approaches are more flexible and domain-independent and are a powerful tool in favour of efforts to optimization of WSNs and Genetic Algorithms has an effective technique for solving combinational optimization problems and also has low computational speed and it is suitable for off-line optimization problems which leads me to believe that it will have a better future for routing in Wireless Sensor

Network. There are many other factors and other routing challenges in WSN that confronts the effective solution like tight coupling between sensor nodes in a real-world environment, sensors are characterized by small footprint since they have finite energy source and communication is the main cause for energy loss and I believe the main focus should be done to solve these problems to get an optimal condition for routing in Wireless Sensor Network. Taking the marking scheme into account I would like to mark my work around 67% because I believe I have done a good literature search on the content of this essay, and I have organized my content in good order and I would mark my Introduction section 6/10 and the routing problems section around 10/15. I would mark my A* search for routing in WSN and EA for routing in WSN 14/20 and 13/20 respectively because I have explained the multiple techniques used in each algorithm to solve the problem in WSN routing using these techniques in detail with suitable figures, tables, formulas, and graphs. I would like to mark my conclusion 14/20 as I believe I have explained what the essay is about and concluded with the results for the work and I have also talked about my opinion on why and how I would solve the problems in WSN routing. For reference I have used APA standard and I have referenced everything that I have used from a source and I expect to get 7/10 in that finally I would like to give myself 3/5 for the format because I have tried to follow the format according to the guideline.

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