Routing Alternatives for Network Lifetime Maximization of WSNs using Heuristic and Fuzzy Logic Approach

Deepak S. Gaikwad, Sampada Pimpale

Abstract: ***Recently many network lifetime maximization approaches and techniques have gained importance and are proposed for enhancing the lifetime of the wireless sensor networks. The distributed and dynamic nature of the WSNs, demand for special requirements in routing protocols in order to minimize the energy consumption and enhance the network lifetime. A large number of routing strategies based on Fuzzy logic approach are proposed in the past for energy aware routing in WSNs. Also heuristic method such as A star routing scheme which is based on informed search method is used to increase network life. A star algorithm finds an optimal shortest path from a source node to target node taking a minimum number of hops and also avoids network partitioning. In this paper the effectiveness of two methods in terms of maximization of network lifetime and balancing the energy consumption has been compared. The simulation results show that the Fuzzy logic approach gives more good results than the A star algorithm in different topographical situations.***

Index Terms*—Wireless sensor *Network, Network lifetime maximization, A star algorithm, Fuzzy logic

I. INTRODUCTION

Wireless sensor network (WSN) consists of large number of cheap and tiny unreliable sensors with limited resources, where the sensors possess sensing, computing and communicating capabilities [1]. Each node in a sensor network composes a radio-transducer, a small microcontroller and a battery. The WSNs are used for gathering information in the situations where terrain, climate and other environmental constraints may deteriorate in the deployment of conventional networks. Primarily these sensors are used for data acquisition and are required to transmit the acquired parameters to special nodes called sinks or base-stations over the wireless link as shown in figure 1. The base-station or sink collects data from all the nodes, and then analyzes this data to draw conclusions about the on-going activity in the area of interest [2]. Sinks or base- stations being powerful data processors can act as gateways to other existing communications infrastructure or to the Internet where a user can have access to the reported data. Sensor nodes in the large-scale data-gathering networks are generally powered by small and inexpensive batteries in expectation of surviving for a long period [3].

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Deepak S. Gaikwad, Dept. of Electronics & Telecommunication, G. S. M. C. O. E, Balewadi, Pune, Pune University, India.
Sampada Pimpale, Dept. of Electronics & Telecommunication, G. S. M. C. O. E, Balewadi, Pune, Pune University, India.

Fig. 2 shows the schematic diagram of components inside a typical sensor node. It comprises of sensing, processing, transmission, mobilizes, position finding system and power units. Sensor node makes its decisions based on its mission, the information it currently has and energy resources.

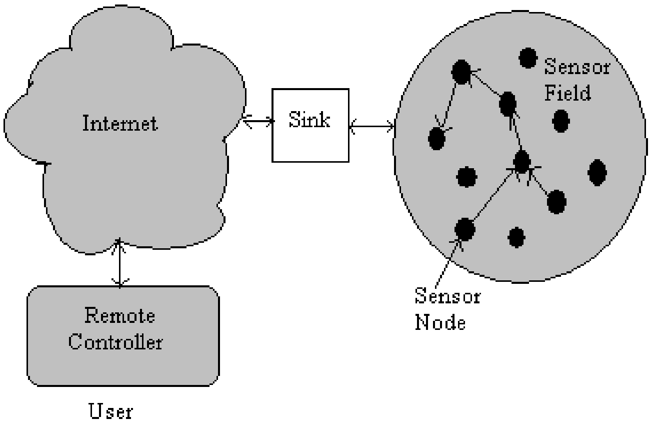

Fig.1. Sensor Network Architecture

The node must have capability to collect and route data either to other nodes or back to an external base station or stations that may be a fixed or a mobile node capable of connecting the sensor network to an existing communication infrastructure or to the internet [4].

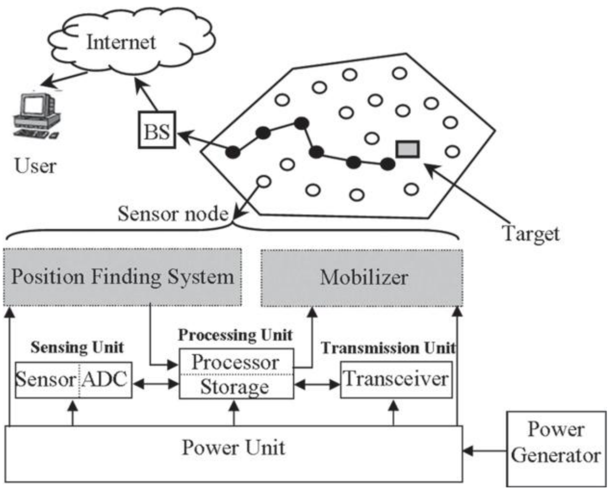

Fig.2. Components of a sensor node

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Due to limitations in the communication range, sensor nodes transmit their sensed data through multiple hops. Each sensor node acts as a routing element for other nodes for transmitting data. Energy is therefore a crucial parameter in power-constrained data-gathering sensor networks. Energy consumption should be well managed to maximize the network lifetime [5]. Unbalanced energy consumption is an inherent problem in WSNs characterized by the multi-hop routing and many-to-one traffic pattern. The uneven energy dissipation can significantly reduce network lifetime. Generally in routing algorithm, the best path is chosen for transmission of data from source to the destination. Over a period of time, if the same path is chosen for all communications in order to achieve battery performance in terms of quick transmission time, then those nodes on this path will get drained fast [3], [5], [7].

The problem with many algorithms is that they minimize the total energy consumption in the network at the expense of non-uniform energy drainage in the networks. Such approaches cause network partition because some nodes that are part of the efficient path are drained from their battery energy quicker. In many cases, the lifetime of a sensor network is over as soon as the battery power in critical nodes is depleted. Therefore for the designers and developers of protocols and applications for WSN, most important is power availability, since in sensor networks the battery life is considered as the network life.

The fuzzy inference system (FIS) optimizes the routing path (depending on the metrics: distance, remaining battery power and link usage) in a distributed fashion [12]. When a data is needed to be sent the protocol selects the optimal path through the FIS. It adjusts the transmit power according to the distance of the receiver node and forwards the data. Each node makes distributed forwarding decisions. This eliminates the necessity of hierarchical networks

In [9] the authors have emphasized on heuristic search technique, called A-Star algorithm, for searching best path for routing in WSN. They suggest that the criteria to search best path is not only to get path with minimum energy consumption but also to see that nodes selected in the path contain enough of residual energy.

Therefore, in this paper, the routing alternatives for network lifetime maximization of WSNS using heuristic and fuzzy logic methods are analyzed and compared to investigate the problems of balancing energy consumption and maximization of network lifetime for WSNs.

II. RELATED WORK

In traditional optimal path routing schemes over WSNs, each node selects specific nodes to relay data according to some criteria in order to maximize network lifetime. Therefore, a good routing method in WSNs involves finding the optimal transmission path form the sender through relay nodes to the destination in order to prolong the network lifetime. Due to this conception, the lifetime problem in WSNs has received significant attention in the recent past.

The Axis-based virtual coordinate assignment protocol and delivery-guaranteed routing protocol in WSN shows minimizing the hop stretch of a routing path in order to reduce the energy cost of end-to-end transmission. A load balanced and lifetime maximization routing protocols in wireless sensor network give a different view for prolonging the network-lifetime that attempts to sustain the availability of the sensors that have less energy by distributing the traffic load to the ones with much residual energy[11]. Opportunistic routing exploited two natural advantages path diversity and the improvement of transmission reliability, to develop a distributed routing scheme for prolonging the network lifetime of a WSN. Distributed algorithms for maximum lifetime routing solve the lifetime maximization problem with a distributed algorithm using the dual decomposition and the sub gradient method. A shortest cost path routing algorithm for maximizing network lifetime based on link costs that reflect both the communication energy consumption rates and the residual energy levels. Uniform balancing energy routing protocols choose the nodes whose residual energies were greater than a certain threshold as routers for other nodes in every transmission round, and distributed the energy load among any sensors to maximize the whole network lifetime.

An Energy-Efficient Multi-path Routing Protocol (EEMRP) [12] has a capability of searching multiple node-disjoint paths and utilizes a load balancing method to assign the traffic over each selected path. In this both the residual energy level of nodes and the number of hops are considered to be incorporated into the link cost function. In weight genetic algorithm, the sensor nodes are aware of the data traffic rate to monitor the network congestion. Optimal Forwarding by Fuzzy Inference Systems (OFFIS) [13] for flat sensor networks proposed selection of the best node from candidate nodes in the forwarding paths by favoring the minimum number of hops, shortest path and maximum remaining battery power, etc.

Algorithm for routing analysis in WSNs utilizing a fuzzy logic at each node to determine its capability to transfer data based on its relative energy levels, distance and traffic load also maximize the lifetime of the sensor networks. A-star algorithm is used to search optimal route from the source to destination in such a way that, there is a pre-defined minimum energy level for sensor nodes so that sensor node doesn't participate in routing if its residual energy level is below that level. Following are the salient features of the routing algorithms proposed in the past:

A. Energy-Efficient Multi-path Routing Protocol (EEMRP): This protocol has a capability of searching multiple node-disjoint paths and utilizes a load balancing method to assign the traffic over each selected path. In this both the residual energy level of nodes and the number of hops are considered to be incorporated into the link cost function. They use a fairness index to evaluate the level of load balancing over different multi-paths. Furthermore, since EEMRP only takes care of data transfer delay, the reliability of successful paths sometimes is limited.

B. Optimal Forwarding by Fuzzy Inference Systems (OFFIS): The OFFIS protocol selected the best node from candidate nodes in the forwarding paths by favoring the minimum number of hops, shortest path and maximum remaining battery power, etc.

C. Fuzzy logic systems: This present a novel algorithm for routing analysis in WSNs utilizing a fuzzy logic at each node to determine its capability to transfer data based on its relative energy levels, distance and traffic load to maximize the lifetime of the sensor networks.

D. A-Star algorithm based Energy Efficient Routing (ASEER): This approach is mainly used to extend lifetime of Wireless Sensor Network. In ASEER, using A-Star algorithm the relay schedule is computed by some centralized entity, with an assumption that the average amount of data generated by each cluster is known. Once schedule is computed, it is broadcasted by the base station. All relay nodes follows this schedule for the current round. After every round, residual energy information of each relay node is updated and current energy level is considered to decide next route for the next round. In most applications of WSNs, sensor nodes are densely deployed in large areas. Once deployed, nodes can never be recharged or replaced. After depleting their energy, nodes turn to die and stop working. Since networks cannot accomplish assigned missions after nodes die.

The lifetime of WSNs is a crucial parameter when evaluating performance of routing protocols. Fig.3 shows the network partition (one part of the network may become disconnected from the destination) due to the death of some sensor nodes. The maximization of lifetime can be formulated as an optimization problem. The variables of this optimization problem are routing parameters at nodes. When having sensed or asked to relay a data packet, each node needs to transmit this packet to a sink. However, it cannot send the packet directly to sinks except that it is a sink's neighbor. So normally a node needs to choose a neighboring sensor as its next hop. When nodes are chosen as the next hops they will influence the energy consumption of the network as well as the lifetime.

From the aforementioned literatures, we note that a number of different metrics have been used to prolong the lifetime of the sensor networks.

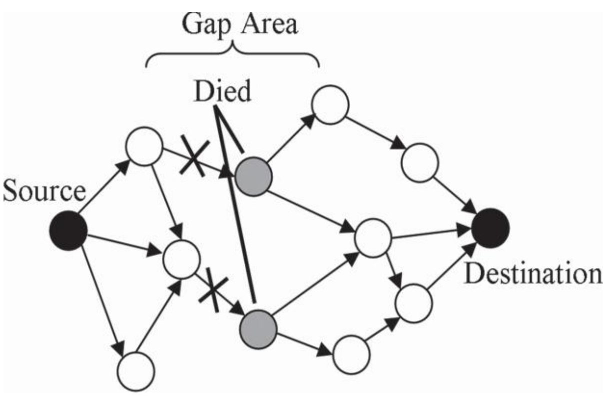

Fig. 3 Network partition due to the death of certain nodes

These metrics are as follows:

1. *Remaining Energy (E):* The most crucial aspect of routing in WSNs is the energy efficiency. Under this criterion, the focus is on the energy capacity (i.e. the current battery charge level) of the nodes. A routing protocol that uses this metric would then favor routes that have the largest total energy capacity from source to destination. In other words, nodes having greater remaining energy participate more than the nodes with limited power. Fig.4 shows an example of a small sensor network, where a source node wishes to transmit a packet to a destination node. The numbers inside the nodes indicate the remaining energy capacity of corresponding nodes.

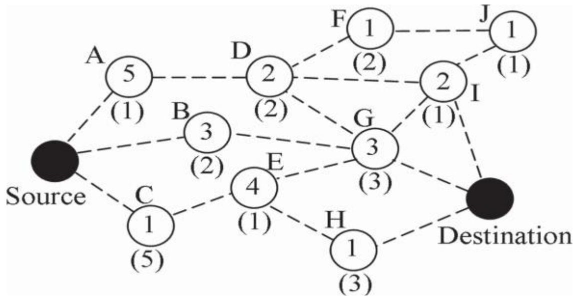

Fig.4 Routing options in a small WSN using different metrics

In this example, a routing protocol could select path A–D–G since it has the largest total capacity (i.e. 10).

2. *Minimum Hop (D):* The most common criterion used in routing protocols is minimum hop (or shortest hop), that is, the routing protocol attempts to find the path from the sender (i.e. source) to the destination that requires the smallest number of relay nodes (hops). The basic idea behind this metric is that using the shortest path will result in low end-to-end delays and low resource consumptions, since the smallest number of forwarding nodes will be involved. In Fig. 4 a routing protocol, under this criterion could select the path B-G which has the minimum hop (i.e.3).

III. FUZZY APPROACH

Fuzzy systems allow the use of fuzzy sets to draw conclusions and to make decisions. Fuzzy sets differ from classical sets in that they allow an object to be a partial member of a set. For example, a person may be a member of the set tall to a degree of 0.8. In fuzzy systems, the dynamic behavior of a system is characterized by a set of linguistic fuzzy rules based on the knowledge of a human expert. Fuzzy rules are of the general form: If antecedent(s) then consequent(s), where antecedents and consequents are propositions containing linguistic variables. Antecedents of a fuzzy rule form a combination of fuzzy sets through the use of logic operations. Fig 5 shows the typical structure of a fuzzy system. It consists of four components namely; fuzzification, rule base, inference engine and defuzzification. The processes of making crisp inputs are mapped to their fuzzy representation in the process called fuzzification. This involves application of membership functions such as triangular, trapezoidal, Gaussian etc.

The inference engine process maps fuzzified inputs to the rule base to produce a fuzzy output. A consequent of the rule and its membership to the output sets are determined here. The defuzzification process converts the output of a fuzzy rule into crisp outputs by one of defuzzification strategies. Thus, fuzzy sets and fuzzy rules together form the knowledge base of a rule-based inference system. Antecedents and consequents of a fuzzy rule form fuzzy input space and fuzzy output space respectively, which are defined by combinations of fuzzy sets. Non-fuzzy inputs are mapped to their fuzzy representation in the process called fuzzification. This involves application of membership functions such as triangular, trapezoidal, Gaussian etc. The inference process maps fuzzified inputs to the rule base to produce a fuzzy output.

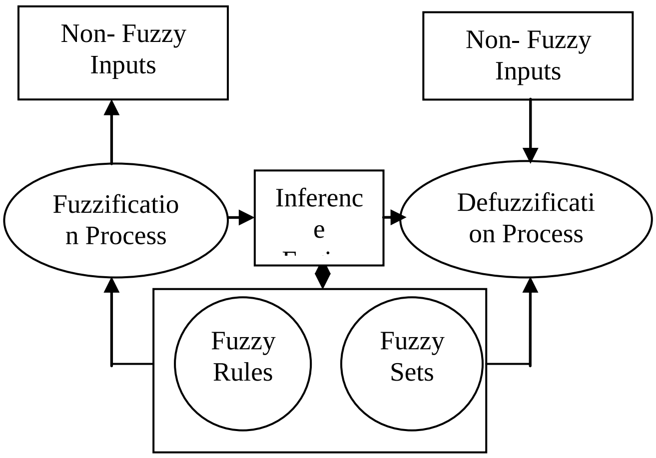

Fig. 5 Block diagram of a fuzzy inference system

A consequent of the rule and its membership to the output sets are determined here. The defuzzification process converts the output of a fuzzy rule into a crisp, non-fuzzy form. Popular inference methods that determine an approximate non-fuzzy scalar value to represent the action to be taken include max-min method, averaging method; root sum squared method, and clipped center of gravity method. Fuzzy logic has been applied successfully in control systems (e.g., control of vehicle subsystem, power systems, home appliances, elevators etc.), digital image processing and pattern recognition.

Unlike classical reasoning in which, a proposition is either true or false, fuzzy logic establishes approximate truth value of a proposition based on linguistic variables and inference rules. A *linguistic variable* is a variable whose values are words or sentences in natural or artificial language. By using hedges like 'more', 'many', 'few', and connectors like 'AND', 'OR', 'NOT' with linguistic variables, an expert can form *rules*, which will govern the approximate reasoning. In the context of crisp sets, a certain element is either a member or a nonmember of a set (in other words, membership is either 1 or 0), whereas in fuzzy logic, a certain element may have partial membership in a set (membership is in the range [0-1]).

A fuzzy membership function is used to compute the membership corresponding to a given value of a linguistic variable. The membership function can be designed in a flexible way in order to reflect the desired *goodness* behavior of an objective corresponding to a given value of the variable. In Fig. 6, if X suggests a collection of objects denoted by x, usually X is referred to as the "*universe of discourse*," and then a fuzzy set A in X is defined by a set of ordered pairs in equation 1:

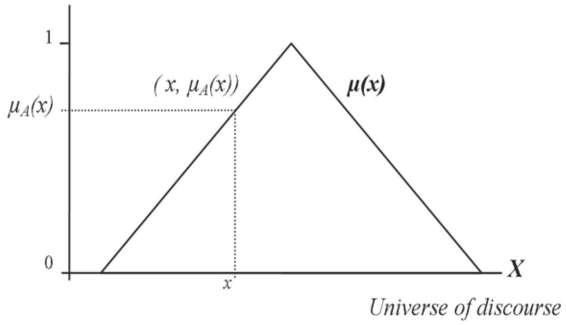

Fig. 6 Membership functions from the pair (x, μA(x)).

$A = \{(x, \mu A(x)/x \in X\}$. ...Eqn. 1

where the function $\mu A(x)$ is called membership function of the object x in A.

This membership function represents a "*degree of belongingness*" for each object to a fuzzy set, and provides a mapping of objects to a continuous membership value in the interval [0...1]. When a membership value is close to the value 1 ($\mu A(x) \rightarrow 1$), it means that input x belongs to the set A with a high degree, while small membership values ($\mu A(x) \rightarrow 0$), indicate that set A does not suit input x very well. In fuzzy systems, the dynamic behavior of a system is characterized by a set of linguistic fuzzy rules based on the knowledge of a human expert. These rules are of the general form IF antecedent(s) THEN consequent(s), where antecedents and consequents are propositions containing linguistic variables. Antecedents of a fuzzy rule form a combination of fuzzy sets through the use of logic operations. Thus, fuzzy sets and fuzzy rules together form the knowledge base of a rule-based inference system. Antecedents and consequents of a fuzzy rule form the fuzzy input space and fuzzy output space respectively are defined by combinations of fuzzy sets.

IV. IMPLEMENTATION OF FUZZY APPROACH

Sensor nodes collect the routing metrics through the localization algorithms, accessing their own battery level and keeping track of the link usage. The fuzzy approach based protocol has the potential to be implemented in both the reactive and proactive manner. In reactive routing, when a node needs to transfer data it generates routing query and asks for its single hop neighbor's information, in order to calculate the routing path. On the other hand, proactive routing, updates the neighboring nodes by periodical broadcasting. By using the FIS different types of metrics (distance, battery power and link usages can be integrated even when the correlation between the metrics is difficult to model mathematically. Each node can make distributed forwarding decisions. This eliminates the necessity of hierarchical networks. The Fuzzy approach is used to determine the optimal value of the node cost of node n that depends on the remaining energy and the distance from a source to the destination sink node to send a data packet. Fig. 7 shows the fuzzy approach with two input variables *R* and *D*, and an output *C*), with universal of discourse [0…5], [0…10], and [0…1], respectively.

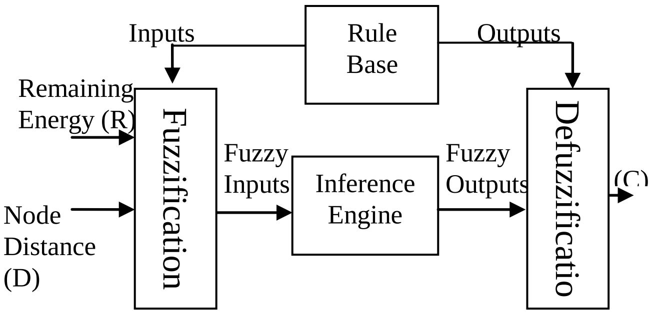

Fig. 7 Fuzzy structure with two inputs (remaining energy and node distance from source to destination) and one output (Chance of selection).

This method uses five membership functions for each input and an output variable, as shown in Fig. 8

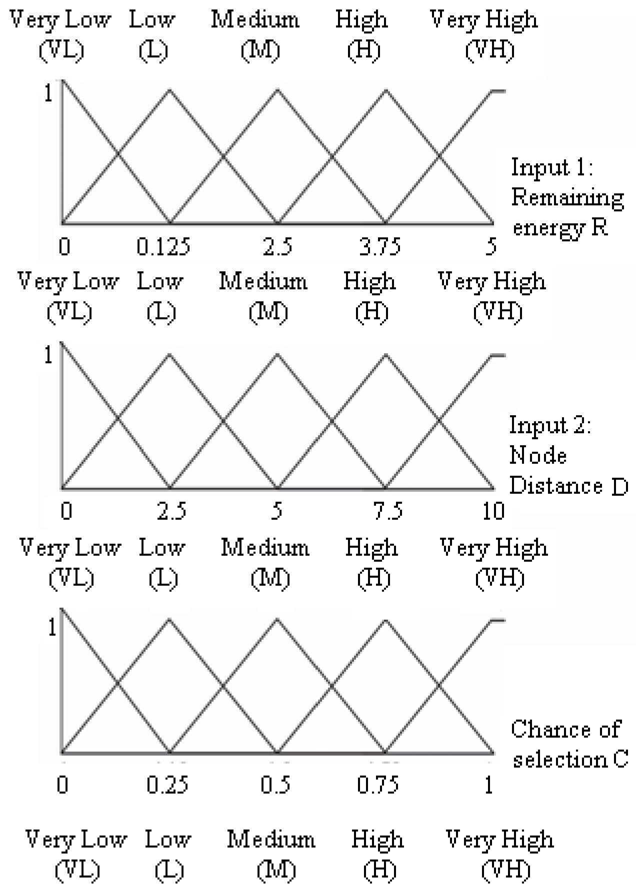

Fig. 8 Membership graph for the inputs (remaining energy and traffic load) and the output (node cost)

For the fuzzy approach, the fuzzified values are processed by the inference engine, which consists of a rule base and various methods to inference the rules. The rule base is simply a series of IF-THEN rules that relate the input fuzzy variables and the output variable using linguistic variables each of which is described by fuzzy set and fuzzy implication operator AND.

Table I IF-THEN Rules

Sr. No	Antecedent		Consequent
	Remaining Energy (R)	Node Distance (D)	Chance of selection (C)
1	VL	VL	L
2	VL	L	VL
3	VL	M	VL
4	VL	H	VL
5	VL	VH	VL
6	L	VL	M
7	L	L	M
8	L	M	L
9	L	H	L
10	L	VH	VL
11	M	VL	H
12	M	L	M
13	M	M	M
14	M	H	L
15	M	VH	L
16	H	VL	VH
17	H	L	H
18	H	M	H
19	H	H	M
20	H	VH	M
21	VH	VL	VH
22	VH	L	VH
23	VH	M	VH
24	VH	H	H
25	VH	VH	H

Table 1 shows the IF- THEN rules, with a total number of $5^2 = 25$ for the fuzzy rule base. As an example, IF *R* is *very high* and *D* is *very low* THEN *C* is *very high*.

All these rules are processed in a parallel manner by a fuzzy inference engine. Any rule that fires contributes to the final fuzzy solution space. At the end, the defuzzification finds a single crisp output value from the solution fuzzy space. This value represents the chance of selection of a node as best candidate to choose the route. Defuzzification is done using centre-of-gravity method given by equation 2.

$$\text{Node Cost} = \frac{\sum_{i=1}^{n} Ui * Ci}{\sum_{i=1}^{n} Ui} \qquad \text{...Eqn. } 2$$

Where U_i is the output of rule base i, and c_i is the centre of the output membership function.

V. A STAR ALGORITHM

Sensor networks are expected to be left unattended for a long period of time. Each sensor running on batteries, this requires an approach that explicitly takes energy into consideration. Each node should be aware of its energy requirements and usage. In some cases it is possible to scavenge energy from the external environment such as solar cells. However, external power supply sources often exhibit a non-continuous behavior so that an energy buffer (a battery) is needed as well. In any case, energy is a very critical resource and must be used very cautiously. Therefore, energy conservation is a key issue in the design of systems based on wireless sensor network. Experimental measurements have shown that data transmission is very expensive in terms of energy consumption, while data processing consumes significantly less. The energy cost of transmitting a single bit of information is approximately the same as that needed for processing a thousand operations in a typical sensor node. In WSN, data collected by sensor nodes are needed to be delivered to base stations. Sometime, data kept in one node could not be directly transmitted to the base station because the base station is far away from that sensor node. A source node cannot send its packets directly to its destination node but has to rely on the assistance of intermediate nodes to forward these packets on its behalf. Therefore, routing protocols are needed where data packets are transmitted via multi-hop manner. Multi-hop means, they are transmitted node by node in order to reach towards base station.

One of the more difficult parts in solving A* is creating a good heuristic function to determine h'(n). A heuristic function differs from an algorithm in that a heuristic is more of an estimate and is not necessarily provably correct. An algorithm is a set of steps which can be proven to halt on a particular given set of input.

The heuristic function in A* is arbitrary, however the better your heuristic is, the faster and more accurate your solution will become. However, therein lies the problem -- deciding a good heuristic. Even with a shortest path example, the heuristic can change, depending on the implementation of the search, and how easy or complicated the heuristic function is going to be.

It uses a distance and a cost heuristic function (usually denoted f(n)) to determine the order in which the search visits nodes in the tree. The distance-plus-cost heuristic is a sum of following two functions:

i) The path-cost function, which is the cost from the starting node to the current node(usually denoted g(n))

ii) And an admissible "heuristic estimate" of the distance to the goal (usually denoted h (n)).

Generally, the A-Star algorithm creates a tree of nodes and maintains two lists, an OPEN list and a CLOSED list. The OPEN list is a priority queue of nodes, where we can select the next least costly node to explore. Initially, the OPEN list contains the starting node. When we iterate once, we take the top of the priority queue, and then initially, check whether it is the goal node, in our case, destination node. If so, we are done. Otherwise, we calculate all child nodes and their associated costs, and add them into the open list.

The OPEN list keeps track of those nodes that need to be examined, while the CLOSED list keeps track of nodes that have already been examined. Each node n maintains the following:

g(n) = the cost of getting from the initial node to n.

h(n) = the estimate, according to the heuristic function, of the cost of getting from n to the goal node.

$$f(n) = g(n) + h(n) \qquad \text{...Eqn. } 3$$

A in the eqn. 3, A-star algorithm may be expressed as follows:

Pseudo-code: Standard A-Star Algorithm

Input: Source and Destination node
Output: Route from Source to Destination node
1. BEGIN
2. Initialize OPEN list
3. Initialize CLOSED list
4. Create start node; call it start
5. Add start node to the OPEN list
6. WHILE the OPEN list is not empty
7. BEGIN
8. Get node n from the OPEN list with the lowest f (n)
9. Add n to the CLOSED list
10. IF n is the same as goal node we have found the solution;
11. Return Solution (n)
12. ELSE
13. Generate each successor node n' of n
14. FOR each successor node n' of n
15. Set the parent of n' to n
16. h (n') = heuristically estimate distance to goal node
17. g (n') = g(n) + the cost to get to n' from n
18. f (n') = g(n') + h(n')
19. Insert n' to the OPEN queue
20. END FOR
21. END WHILE
22. END

VI. IMPLEMENTATION OF A STAR ALGORITHM

In this, the base station prepares the routing schedule and broadcast it to each node.

A-star algorithm which is used to find the optimal route from the node to the base station is applied to each node. A-star algorithm creates a tree structure in order to search optimal routing path from a given node to the base station. The tree node is explored based on its *evaluation function f(n)*. The function we used is given by eqn. 3 as:

$$f(n) = g(n)+h(n) \qquad \text{...Eqn. 3}$$

For every intermediate node n, ($1 \leq n \leq N$, where N is total number of relay nodes in WSN), g(n) will be actual cost to reach to node n from source node S and h(n) will be estimated, heuristic cost from the current node n to the destination node D. The base station prepares routing schedule and will be broadcasted to each relay node. A-Star algorithm, to find optimal route from relay node to the base station will be applied for each relay node. The relay node where this algorithm is applied will be the source node and the base station will be destination node. Such N different routes will be created and this all information is consolidated. Array has N number of indices. Value at i^{th} index will represent node number as to where node i will be sending data, which in turn, goes to the base station in a same way. After current routing schedule is broadcasted, all relay nodes will follow it and will send data accordingly. At the end of the current round, the base station calculates and updates energy level information for each relay node. Then base station will again search for a new routing schedule which will consider current energy levels. This will be another round. This process will continue until any of the relay nodes is failed due to depletion of energy. Total number of rounds is calculated and is used as a parameter to count network life time.

Generally efficient and energy oriented decision for choosing best route is the path which consumes less energy. Only considering total amount of energy consumed, will not be efficient because it will drain some of the nodes which are on the efficient path. Those nodes will participate in more number of schedules and will get out of energy earlier. This may result in network partition. This scenario is avoided by introducing different levels of energy of node. While making decision for routing, in a route if a node is below a threshold level of residual energy, then alternate route is selected with node having more energy than threshold level. This alternate route will give life extension to those nodes which were selected in the first attempt, thus the network life too, gets extended. Out of many possible solutions, those will be strong candidate to win who have more number of nodes having energy greater than Level1. Thus, healthy nodes will participate in routing and weak nodes will get rest, thus overall network lifetime can be extended.

VII. PERFORMANCE EVALUATION

To demonstrate the effectiveness of the methods in terms of balancing energy consumption and maximizing network lifetime, we compared A-star search algorithm with Fuzzy approach for two different topographical areas. The two methods use the same routing criteria namely, the remaining energy, the minimum hop, and the traffic load in selecting the optimal path from the source node to the sink node. Experimental results obtained under various network scenarios indicate that both the Fuzzy approach and A-star algorithm give optimal performance in terms of the network lifetime as well as the average energy consumption with slight changes.

A. TROPOLOGICAL SETUP

The simulations are carried out in MATLAB. 100 sensor nodes are randomly deployed in a topographical area A of dimension 100 m × 100 m. Another set of 100 sensor nodes are randomly deployed in a topographical area B of dimension 200 m × 50 m. Both topographical areas A and B have the sensed transmission limit of 30 m. The performance of both methods is tested in these two topographical areas. There is only one data sink which located at (90 m, 90 m) for area A and at (180 m, 45 m) for area B. All sensor nodes have the same initial energy 0.5J. Simulations are done using the values 50nJ/bit and100nJ/bit/m2 for E_{elec} and E_{amp}, respectively. Table 2 presents the systems parameters in details.

Table II Simulation parameters

Parameter		Value
Topological Area (meters)	A	100m X 100m
	B	200m X 50m
Sink location (meters)	A	(90, 90)
	B	(180,45)
Number of nodes		100
Limit of transmission		30m
Initial energy of node		0.5J
E_{elec}		50nJ/bit
E_{amp}		$100pJ/bit/m^2$
Packet data size		250 b
Number of transmission		$2 X 10^4$
Maximum traffic node's		10

B. SIMULATION SETUP

The different duration of time corresponding to the first dead node computed using the three different approaches in both areas *A* and *B* is listed in Table 3.

Table III Number of rounds with the First dead node in both areas A and B

Approaches	A-Star	Fuzzy
Lifetime of the first dead node in A area	1352	2304
Lifetime of the first dead node in B area	2043	2234

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As the round number increases in the two areas, better energy balance in a WSN is achieved by fuzzy approach compares with A star method in both areas *A* and *B*.

VIII. CONCLUSION

In wireless sensor networks where nodes operate on limited battery energy efficient utilization of the energy is very important. The network lifetime is highly related to the route selection and to efficiently route data through transmission path from node to node and to prolong the overall lifetime of the network, we compared both Fuzzy approach and A-star algorithm. The performance of fuzzy approach method evaluated and compared with A star algorithm method under the same criteria in two different topographical areas shows that Fuzzy approach is more efficient than A star algorithm approach.

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AUTHORS PROFILE

Deepak Gaikwad is a Final year M.E. student of Department of Electronics and Telecommunication, G. S. M. C. O. E., Balewadi, Pune University. His area of interest is Embedded and VLSI.

Sampada Pimpale is a Assistant Professor, in Department of Electronics and Telecommunication, G. S. M. C. O. E., Balewadi, Pune University. Her area of interest is Fuzzy Logic.