ASEER : A ROUTING METHOD TO EXTEND LIFE OF TWO-TIERED WIRELESS SENSOR NETWORK

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ABSTRACT

Various routing protocols have been designed and developed for Wireless Sensor Networks. They face various challenges. Sensor nodes are strongly energy and storage constrained, also failure rate of sensor node is very high. As, energy conservation in such network is of paramount importance to extend the lifetime of network, while sending data to the Base station, some routing mechanisms which consider all these parameters are required.

There are several techniques for routing in wireless sensor network for data gathering with aggregation and for data gathering without aggregation. Using Minimum transmission energy model and Minimum hop routing model techniques it may happen that the same path is used for more times and nodes on this route gets drain from energy. This leads to network partition and routing algorithm failure. In this paper, we have presented A-Star algorithm based Energy Efficient Routing (ASEER) based on informed search. We have used A-Star algorithm to search optimal route from source to destination in such a way that overall life of network is extended. Pre-defined minimum energy level (Level1) for sensor nodes have been used so that sensor node don't participate in routing if its residual energy level is below this level and other better path is still available. If there exist no such path, then this node can be part of routing.

KEYWORDS

Wireless sensor network, Routing algorithm, A-Star algorithm

1. INTRODUCTION

In Wireless Sensor Network (WSN), light-weight, low power and small size sensor nodes are used. Sensor node gets operated by making use of a small battery attached to it. These batteries have some initial energy and they lose some part of energy after every communication they make. The energy they lose is proportionate to the distance of communication. Sensor node lose fraction of energy after every message they transfer or receive and eventually battery gets drained. There is no way to recharge these batteries in case, the sensors are deployed in hostile environment or in a kind of environments where it is hard to reach. Sensors nodes are used for monitoring physical phenomena like temperature, humidity, vibrations and so on [1, 20]. The sensor network should have a lifetime long enough to fulfil the application requirements. In many cases several months or even years of lifetime is required. How to prolong network lifetime to such a long time is the vital question

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Deployment of sensor nodes is done either in random fashion or in pre-defined way. The sensor node performs needed measurements from its surroundings, process this data and transmit it to

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the base station. The base station collects data from all these nodes and uses it as per the application. Nodes in sensor networks have limited computational power, limited energy resources and memory. These restrictions put a limit on routing algorithms to be used.

Generally in routing algorithm, the best path is chosen for transmission of data from source to destination. Over the period of time, if same path is chosen for all communications in order to achieve better performance in terms of quick transmission time, then those nodes which are on this path will get drained earlier. The problem with many routing algorithms is that they minimize total energy consumed in the network with the expense of non uniform energy drainage in the network. Such approaches cause network partition because some node which are part of the efficient path, are drained from their battery energy quicker. When these nodes get exhausted, they may break network into parts because of unavailability of other path. In many cases, the lifetime of a sensor network is over as soon as the battery power in critical nodes is depleted [2].

The WSN may consist of thousands of sensor nodes. Such a large network usually cannot be efficiently operated without some structuring. Clustering is a useful mechanism in wireless sensor networks that helps to cope with scalability problems and, if combined with in-network data aggregation, may increase the energy efficiency of the network and makes the network more vulnerable to attacks.

Some special nodes, called relay nodes can also be used within the network, for balanced data gathering to extend life of network. In case of hierarchical sensor network, cluster head is called as relay node.

There are several challenges in wireless sensor network. Sensor nodes are tightly constrained in terms of energy, processing, and storage capacities, so they require careful resource management. As node failure is occurred frequently in WSNs which results in unpredictable and frequent topological changes. So the routing protocol must adapt to frequent changes of the WSNs topology.

A Genetic Algorithm (GA) based approach for energy efficient routing has been proposed by Ataul Bari et. al[3]. They have suggested this approach for two-tiered sensor network for data gathering with aggregation. In [4], Genetic Algorithm based approach for data gathering without aggregation has been proposed. In this approach, a pre-defined threshold level (*Level1*) energy is considered as the threshold residual energy in the sensor node. If it is found, that one or more node having residual energy less than the *Level1* energy in the route between source to destination, then, another route with number of nodes below residual energy of *Level1* lesser than the previous route solution will be sought. In this approach, total energy consumed and total number of nodes below *Level1* has been used as criteria to choose best route.

In this paper, we have emphasized on heuristic search technique, called A-Star algorithm, for searching best path for routing in WSN. 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. This will make sure, that overall lifetime of sensor network is extended. We have used same concept of a pre-defined threshold level, *Level1*, of residual energy. We have simulated GA based approach of [4] and A-Star algorithm for routing in WSN for data gathering without aggregation for comparison.

To find best path, Warshall’s algorithm [5, 6] can be used. Warshall’s algorithm compares all possible paths through the graph between each pair of vertices. This is a non adaptive algorithm and it does not consider current level of energy of sensor nodes to decide route. We have also simulated Warshall’s algorithm and compared with our approach.

2. THEORETICAL BACKGROUND & LITERATURE SURVEY

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 behaviour 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 [21]. 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 [22].

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 can not 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.
In this chapter, we will discuss informed and heuristic search, A-Star algorithm, Network model and two tired Wireless Sensor Network.

2.1. Overview of A-Star algorithm

A-Star algorithm is used to find path and to traverse graph efficiently. It uses heuristics for decision making. The A-Star algorithm [7] is a best-first search algorithm that finds the optimal path from source to destination.

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); intuitively, this is the estimate of the best solution that goes through n.

The heuristic function must be admissible, that is, it must not overestimate the distance to the goal or, in other words estimated cost must be less than the actual cost. This produces computationally optimal results. Thus, for an application like routing, h(n) might represent the straight-line distance to the goal, since that is physically the smallest possible distance between any two nodes. The most essential part of the A-Star algorithm is a good heuristic estimate function. This can improve the efficiency and performance of the algorithm [8].

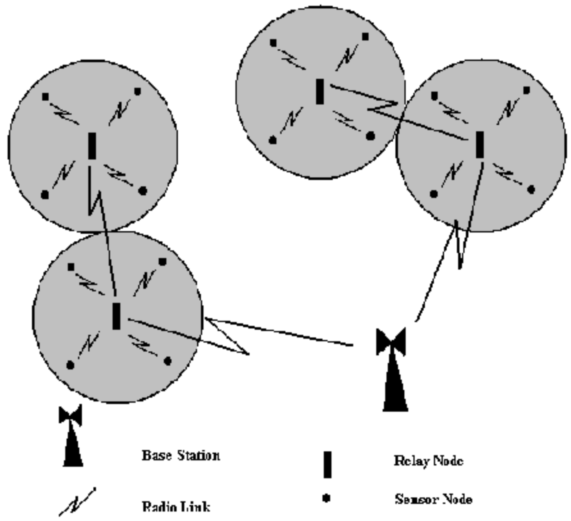
Each node also maintains a pointer to its parent, so that later we can retrieve the best solution found, if one is available. A-Star has a main loop that repeatedly gets the node, say n, with the lowest f(n) value from the OPEN list (in other words, the node that we think is the most likely to contain the optimal solution). If n is the goal node, then we are done, and all that is left to do is return the solution by backtracking from n. Otherwise, we remove n from the OPEN list and add it to the CLOSED list. Next, we generate all the possible successor nodes of n and will be put in the OPEN list. This algorithm is shown in the pseudo code as follows:
Pseudo-code : Standard A-Star Algorithm

```
Input      :     Source and Destination node
Output     :     Route from Source to Destination node
BEGIN
 Initialize OPEN list
 Initialize CLOSED list
 Create start node; call it start
 Add start node to the OPEN list
 WHILE the OPEN list is not empty
 BEGIN
      Get node n from the OPEN list with the lowest f(n)
      Add n to the CLOSED list
      IF n is the same as goal node we have found the solution;
            return Solution(n)
      ELSE
            Generate each successor node n' of n
      FOR each successor node n' of n
            Set the parent of n' to n
            h(n') = heuristically estimate distance to goal node
            g(n') = g(n) + the cost to get to n' from n
            f(n') = g(n') + h(n')
            Insert n' to the OPEN queue
      END FOR
 END WHILE
END
```

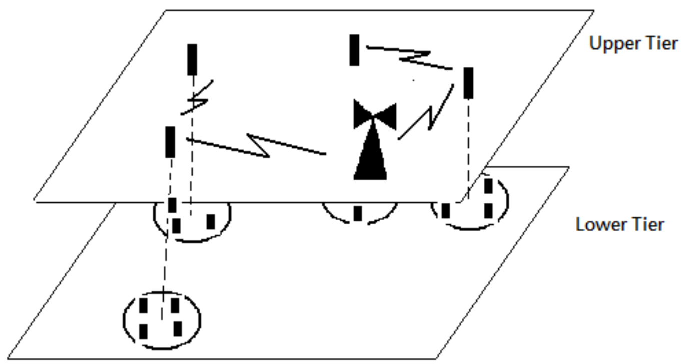
2.2. Network Model

Many researchers have proposed the use of some special nodes, called relay nodes within the network, for balanced data gathering to extend life of network. In case of hierarchical sensor network, relay nodes can be used as cluster head. These cluster heads are equipped with higher energy as compared to the sensor nodes.

In this paper we will be refereeing mainly to the sensor network model depicted in Figure 1. This figure shows that sensor network is divided in cluster where each cluster contains one relay node and many sensor nodes. There is also one Base station where information is forwarded by sensor nodes via relay nodes. Each relay node can communicate either with other relay nodes or to the Base station. Sensor nodes can communicate with relay nodes of their cluster. Clustering strategies for this model can be referred from [12].



(a)



(b)

Figure 1 : (a) Two Tiered Sensor Network (b) A Logical Topology of Two Tier

For this model, a two-tiered wireless sensor network has been considered, with N relay nodes (acting as cluster heads). They are labelled as node numbers 1, 2, 3, . . . , N and one base station, labelled as node number N+1. This labelling is done for representing the routing solution in form of an array. Let D be the set of all sensor nodes, and Di, $1 \leq i \leq N$, be the set of sensor nodes belonging to the ith cluster, which has relay node i as its cluster head. We assume that each sensor node belongs to exactly one cluster i.e., $D = D_1 \cup D_2 \cup \ldots \cup D_N$ and $D_i \cap D_j = \Phi$ for $i \neq j$.

A number of different metrics have been used in the literature to measure the lifetime of a sensor network. In [9], the lifetime of a sensor network has been defined as the minimum of (i) the time when the percentage of nodes that are alive (i.e., nodes whose batteries are not depleted) drops below a specified threshold, (ii) the time when the size of the largest connected component of the network drops below a specified threshold, and (iii) the time when the volume covered drops below a specified threshold. The work of [10] has defined the lifetime of the network as the lifetime of the sensor node that dies first. In [11], a number of metrics are used to define the network lifetime, e.g., N-of-N lifetime (i.e., time till any relay/gateway node dies), K-of-N lifetime (i.e., time till, a minimum of K relay/gateway nodes are alive) and m-in-K-of-N lifetime (i.e., time till, all m supporting nodes and overall a minimum of K relay/gateway nodes are alive). In this approach of routing using A-Star algorithm, N-of-N lifetime has been used.

2.3. Routing in Sensor Network through Relay Nodes

The type of network shown in figure 1 consists of a number of sensor clusters and a base station. Each cluster is deployed around a pre defined location. A cluster contains number of wireless sensor nodes and a relay node. Each sensor node can capture and transmit data to the relay node. The relay node then sends these data to the base station. Relay node may perform in-network information processing by data aggregation. Performing aggregation on data is application dependant.

One of the important measures of WSN is the network life time. For our model, whenever any relay node runs out of energy, communication link between various relay nodes and the base station will break. This is considered as the end of life of the network. Since life time of each relay node depends on energy consumption, it is important to preserve residual energy of these relay node in such a way that overall network life time is extended.

Many researchers dealing with routing in network of relay node adopt the flow-splitting model. In flow-splitting model, flow of outgoing data from a node is divided in the number of sub flows. This approach has a number of limitations, including the requirement by the relay nodes to perform complex routing functions and costly packet level power control for nodes that are equipped with a single transmitter [14]. The flow-splitting approach is not suitable for use in conjunction with directional antenna. Therefore, we are focusing on non-flow-splitting routing scheme using multi hop data transmission model, to extend life time of relay node network. Traditional multi-hop schemes used for routing in sensor networks include:

- Minimum transmission energy model, where each relay node i transmit to its nearest neighbour j, such that the relay node j is closer to the base station than the relay node i.
- Minimum hop routing model, where each relay node finds a path to the base station that minimizes the number of hops.

In this paper, we consider two-tiered sensor networks and present an A-Star algorithm based approach to determine a suitable routing strategy for upper-tier relay node networks which is shown in figure 1(b).

3 A-STAR ALGORITHM BASED ROUTING

Given a collection of n relay nodes, numbered from 1 to n, and a base station, numbered as n+1, along with their locations, the objective of the A-Star algorithm is to find a schedule for data gathering in a sensor network, such that the lifetime of the network is maximized. Each sensor node transmits exactly one packet of data containing a fixed number of bits, in each round. Each period of data gathering is referred to as a round [13], and the lifetime is measured by the number of rounds until the first relay node runs out of power. In other words, the N-of-N metric is used to measure the network lifetime. It is also assumed that the initial energy provisioned in each relay node is equal.

In our model, the routing schedule is computed by some centre entity, in this case, it is a base station. We have assumed that average amount of data transmitted by each relay node is fixed and is known to the base station. Base station calculates optimal routing schedule and broadcasts it. Every cluster head (relay node) follows this schedule. This process of finding optimal path, broadcasting it in the network and sending data from all clusters to the base station by following this routing schedule is repeated in every round. Computation of routing schedule is done dynamically with the consideration of current level of energy of each relay node. For this, normally it may require the relay nodes to report their residual energy periodically to the base station. The base station can then determine the routing schedule based on this updated information.

We have assumed that the number and location of relay nodes are predetermined. Hence, distances between various relay nodes are known. With the known distance, energy consumed for data transmission and data reception can be calculated and updated throughout.

3.1. Routing Schedule

A-Star Algorithm is basically used to find efficient path between any sources to destination. A-Star algorithm makes decision on the basis of value f(n), where f(n) = g(n) + h(n). In a network consider the source node is S and the destination node is D. 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.

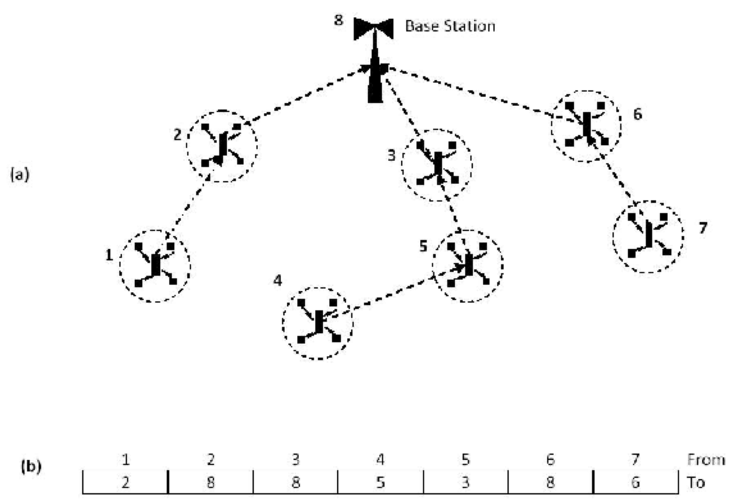


Figure 2 : (a) Two tired WSN with labelled relay nodes and base station (b) Routing schedule represented in form of an Array

In our model, base station will prepare routing schedule and will be broadcasting to each relay nodes. 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. This consolidated route information is put in an array. This is shown in figure 2(b). Figure 2(a) shows two tiered WSN, as discussed earlier. Dotted lines are showing route for each relay nodes.

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, will go to the base station in a same way. For example in figure 2(a), node 4 will send data to node 5, then node 5 will send data to node 3 and finally node 3 will send data to node 8, which is the base station. This routing information is stored in Array form, as shown in figure 2(b).

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 will calculate and update 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.

3.2. Minimum Energy Concept

Generally efficient and energy oriented decision for choosing best route would be 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 can be avoided and all nodes of the network can take balanced load in terms of energy.

This can be achieved by introducing different levels of energy of node. Say, a node having E_{init} initial energy has another mark of energy, Level1 of energy (say 40% of E_{init}). While making decision for routing, in a route if a node is below Level1 of residual energy, then alternate route is selected with node having more energy than Level1. 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.

3.3. Total Energy Consumed

There are two approaches of data gathering, (i) data gathering with aggregation and (ii) data gathering without aggregation. For different types of applications different approaches are taken.
To calculate life of a network, we are counting total number of rounds. This can also be counted, as follows:

$$R_{net} = \frac{E_{initial}}{E_{\max}} \tag{1}$$

where R_{net} is the network lifetime in terms of rounds and $E_{initial}$ is the initial energy of a relay node. We assume that the value of $E_{initial}$ is known beforehand and is the same for all relay nodes initially. E_{max} is the maximum energy dissipated by any relay node in the particular routing schedule.

It is assumed that $E_{initial}$ is known initially and will remain same. But E_{max} is the maximum power dissipated by any node of the routing schedule. For the routing schedule as shown in figure 2(b), E_{max} will be maximum energy dissipated from node 1 to 2, from node 2 to 8, from node 3 to 8, from node 4 to 5, from node 5 to 3, from node 6 to 8 and from node 7 to 6. i.e. E_{max}= Max Energy Dissipated from node (1→2, 2→8, 3→8, 4→5, 5→3, 6→8, 7→6).

The equation 1 can be useful when, we consider data gathering with aggregation. But for data gathering without aggregation, this approach of counting network life will not be useful. Aggregation can be performed when the data from different sensors are highly correlated but data aggregation is not applicable in all sensing environments. Imagine a scenario where the data being transmitted by the nodes are completely different (no redundancy) e.g. video images from distant regions of a battlefield. In such situations, it might not be feasible to fuse data packets from different sensors into a single data packet, in any meaningful way. This implies that the number and size of transmissions will increase, thereby draining the sensor energies much faster.

The problem is finding an efficient schedule to collect and transmit the data to the base station, such that the system lifetime is maximized [15].

3.3.1. Data gathering without Aggregation

To understand why we need special attention for those applications where data gathering is done without aggregation, let us understand from figure 3 which shows part of the sensor network for one of the routing schedule for data transfer. For the case of data aggregation, node 4 will aggregate data and send it to base station only once, thus energy will be consumed only once. But in case of data gathering without aggregation, node 4 will send data to the base station for three times. First, sent by node 1 to node 4 and then to the base station. Second, sent by node 2 to node 4 and then to the base station. Third, sent by node 3 to node 4 and then to the base station. This way, it will consume almost 3 times higher energy than the earlier case. While for node 1, 2 and 3 energy consumption will not differ in either of data gathering technique.

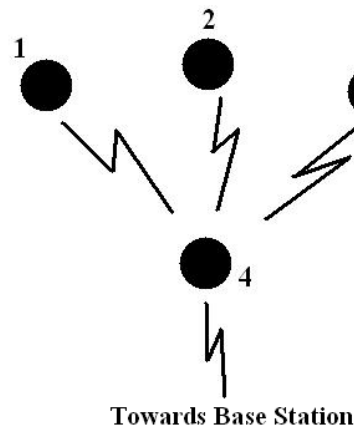


Figure 3 : Part of the Sensor network

4 PROPOSED ASEER ALGORITHM

In this paper, we have proposed A-Star algorithm based Energy Efficient Routing (ASEER) algorithm. A-Star algorithm creates tree structure in order to search optimal route from given source to the destination. A tree node will be explored based on its *f(n)* value, which A-Star algorithm uses for optimal path searching, where *f(n) = g(n) + h(n).*

4.1. Threshold Energy level, *Level1*

In our approach, in addition to *g(n)* and *h(n),* we have also taken another parameter to measure strength of a route. This parameter keeps track of the current energy level in the sensor node. As introduced earlier, a pre defined threshold energy level, *Level1* can be used as a threshold level for a sensor node. If sensor node's residual energy goes below this level, the algorithm should avoid this node while searching for a route, rather, it should search for alternative path, where no node having residual energy below Level1 is there.

This new parameter *l(n)* is incorporated along with *g(n)* and *h(n)* to calculate estimated cost function *f(n). l(n)* is the path cost count of weak node having less energy, will keep a counter of how many nodes in the current path are below *Level1* energy level.
Thus, Estimated cost function *f(n)* carries two parameters. First parameter is summation of *g(n)* and *h(n)* and the other parameter is *l(n)* as shown in equation (2).

$$f(n) = (g(n) + h(n) , l(n)) \quad (2)$$

Following examples will be helpful to understand the concept of l(n). Three examples are taken and each carries two routes. The last row of each example is the routing decision, which shows with clarification that which route is chosen for routing.

Example 1:				
	g(n)	*h(n)*	*f(n) = g(n) + h(n)*	*l(n)*
Route 1	70	35	105	0
Route 2	85	15	100	0
Routing Decision	Since both routes have same value of *l(n)* and Route 2 has minimum value of *f(n),* Route 2 is selected for routing.			

Example 2:				
	g(n)	*h(n)*	*f(n) = g(n) + h(n)*	*l(n)*
Route 1	70	35	105	2
Route 2	85	15	100	2
Routing Decision	Since both routes have same value of *l(n)* and Route 2 has minimum value of *f(n),* Route 2 is selected for routing.			

Example 3:				
	g(n)	*h(n)*	*f(n) = g(n) + h(n)*	*l(n)*
Route 1	70	35	105	2
Route 2	85	15	100	3
Routing Decision	Since Route 1 has minimum value of *l(n),* irrespective of value of *f(n)* Route 1 is selected for routing.			

From above examples, it is seen that routing decision is made based on value of *l(n).* If *l(n)* is same, then only value of *f(n)* is checked for further comparison.

For A-Star algorithm implementation, we have prepared and used following data structures with below mentioned members:

- A tree node {A Sensor node element, M number of children pointers, A pointer to the parent node, value of *g(n), h(n), l(n)*}
- A sensor node {Identification of node, Residual energy, List of neighbours, Number of neighbours}

Pseudo Code for Proposed ASEER Algorithm

```
Input :     Sensor Network
Output :    Life of Sensor Network in terms of rounds
BEGIN
INITIALIZE_NETWORK ( )
ESTIMATE_DISTANCE ( )
WHILE NOT END_ASTAR ( )
      INITIALIZE_SOL_ARRAY ( )
      FOR each node i in the Network DO
            CREATE_TREE (i)
            PREPARE_SOL_ARRAY ( )
      END FOR
      BROADCAST_SOLUTION ( )
      UPDATE_ENERGY ( )
      COUNT_ROUND = COUNT_ROUND + 1
```

```
13. END WHILE
14. PRINT COUNT_ROUND
15. END
```

Pseudo code for proposed efficient routing algorithm in WSN using A-Star algorithm contains some functions, which are described in details as follows:
INITIALIZE_ NETWORK ( ) : This function will initialize the network, in terms of node id, node energy, node neighbours etc.

ESTIMATE_DISTANCE ( ) : This function will find estimated distance from each node to the base station. Calculation of finding estimated distance from current node to the base station can be carried out from the methods mentioned in [16, 17]. This distance will be useful to calculate energy consumption between two nodes. Base station will be able to update node's residual energy once routing schedule is prepared. This estimated distance is also useful to get our heuristic function, *h(n)*.

END_ASTAR ( ) : This function will check whether to terminate the process or not. This will check residual energy of each node of the network. If any node's residual energy falls to 0, i.e. any node is fail due to depletion of energy, this function will return true otherwise, it will return false.

INITIALIZE_SOL_ARRAY ( ) : This function will initialize solution array where routing schedule going to be stored. Routing schedule is an array having N number of index values, if total number of nodes in WSN is N. Value at index *i* will contain id no of the next node where node *i* will be sending data. This routing schedule is shown in figure 2(b).

CREATE_TREE (*i*) : This function will expand whole tree for the node *i*. This tree is created using A-Star algorithm, to search optimal path from source node *i*, to the destination node, base station. At the end, solution found in the tree is stored in the form of an array in the solution array.

PREPARE_SOL_ARRAY ( ) : This function will be called after tree for a node is created. This will prepare solution array. This solution array will be filled up in the same manner, by every node. Every node will partially fill the solution array. When all nodes are covered, this solution array is ready and it is called the routing schedule.

BROADCAST_SOLUTION ( ) : This function will be called after every node is ready with its tree and routing schedule is prepared. This routing schedule is broadcasted by the base station in a network. All nodes in the network will follow routes presented in the routing schedule. Every node will obtain next node as to where to transmit data, from this routing schedule.

UPDATE_ENERGY ( ) : This function will update residual energy level of each node as per the routing schedule, stored in the solution array. In our approach, we have considered data gathering without aggregation. So, energy updation will be performed as mentioned in the section 3.3.1.
COUNT_ROUND : This is a global variable which keeps track of total number of rounds, the network works for. After every round, energy of all nodes will be updated, new routing schedule will be searched, this schedule will be broadcasted and all nodes will follow this new schedule for transferring their data. This variable is incremented by one at every iteration. When any relay node is exhausted and failed because of energy depletion, our algorithm will stop. We are measuring life time of WSN in terms of rounds.

4.1 Calculation of Heuristic values with Energy Level

Calculation of estimated cost function *f(n)* in A-Star algorithm is simple. It takes into account value of path cost function, *g(n)* and value of heuristic estimated function *h(n).* We have added one more parameter, path cost count of weak node *l(n),* which is number of nodes below pre-defined energy level, *Level1*.

The path cost function, *g(n)* is calculated as : For the node n, whose parent node is *p*, *g(n)* is calculated as the summation of distance from node *p* to node *n* and value of *g(p),* where *g(p)* is the path cost function of the parent node, *p.* We have assumed that node n is the intermediate node in the route from source to the destination. Thus, path cost value of parent node plus, distance of parent node to the child node, *n,* will become path cost value of the node *n.* Path cost function gives the value in terms of cost to reach from source node to the current node. This value is the actual value.

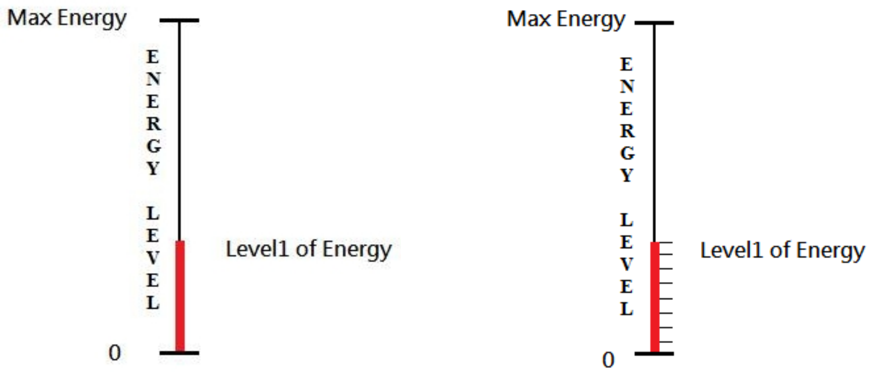
The heuristic estimate function, *h(n)* is calculated as: For each node, estimation of distance to the base station, which has been done initially will be considered as the heuristic estimation value for the sensor node. This value will give estimation of how far the destination is from the current node. This value must not overestimate the actual cost. This is called admissibility of the function. This ensures optimal result.

The parameter, path cost count of weak node *l(n),* which is number of nodes below energy level, *Level1* is calculated as : If a node n whose parent node is *p*, is the intermediate node from source node to the destination node, *l(n)* will keep count of total number of nodes which are on this route and are below pre-defined threshold level of energy *Level1*. Residual energy of the current node *n* will be checked, and if it is found less than *Level1* energy, then *l(n)* will be *l(p) + Incremental_factor*, where *l(p)* is the path cost count of weak node for parent node *p* and *Incremental_factor* is a value, which is added in *l(n)* parameter as per the strategy.

Strategy for assigning value to *Incremental_factor* can be as simple as to assign 1 to it. It means, it will add 1 to the value of *l(n)* for every node encountered, having lesser energy than *Level1*. We initially tried this approach then, we modified this approach little bit and applied another approach to assign value to the *Incremental_factor*. The first approach is shown in Fig. 4.1 (a) and the second approach is shown in figure 4(b). The red region (dark line) of energy in the figure 4 indicates that the node is weak in terms of energy power. So, if residual energy of a node falls in this region, it is considered as a weak node and it should be avoided from taking part in the routing, provided some strong nodes are still available.

First approach was to assign 1 to the *Incremental_factor* if residual energy is found below *Level1*, The disadvantage was, that, if a node *x* having 0.1 % of initial energy left and the other node, *y*, having 30% of initial energy left, both of them are treated equally, as residual energy level of both of them are below *Level1*. This does not provide better solution.
To avoid these circumstances we applied concept of assigning value proportionate to the energy level to *Incremental_factor*. Hence, node *x* having 0.1 % of initial energy left, will be assigning much larger value in Incremental_factor as compare to the node *y* having 30% of initial energy left. You can see in figure 4 (b), the *Level1* is further divided in sub levels and assignment of *Incremental_factor* in each sub level is different. It gets incremented more and more as it goes nearer to zero value.

Assignment of value to the *Incremental_factor* in our approach is taken as proportionate to the residual energy left in the sensor node. E.g. It will be more for residual energy left 0.1% of initial energy and will be less for 30% of initial energy.



(a) Single value of Level1 (b) Level1 is divided in multiple levels

Figure 4 : Energy Level of a sensor node, Level1

5. EXPERIMENTAL RESULTS

For our experiments, we have used following first order radio model for communication energy dissipation [18].

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

Where $d_{i,j}$ is the Euclidian distance between node i and j, α2 is the transmit energy coefficient, β is the amplifier coefficient, b_{ti} is amount of data to transmit from node i to another node and m is the path loss exponent, $2 \leq m \leq 4$. E_{Ti} is total transmit energy dissipated.

Similarly, the receive energy, E_{Ri} is calculated as follows:

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

Where b_{ri} is the number of bits received by relay node i and α1 is the receive energy coefficient.

Hence total energy dissipated by a node i for data to receive and then to transmit it further is E_i.

$$E_i = E_{Ti} + E_{Ri}$$

We consider both type of energy in computation of energy consumption. For simulation, the values for the constants are taken same as in [18] as follows:

i. α1= α2=50 nJ/bit
ii. β=100 pJ/bit/m2 and
iii. The path loss exponent, m=4
iv. The initial energy of each node, E_{init}=5J.

Performance of the network lifetimes in terms of rounds is improved when we divide *Level1* energy level further into sub levels. This is also proved experimentally. These two approaches, shown in figure 5 for different networks of different number of relay nodes are compared and shown.

It is observed from the Figure 5 that, network life time in terms of round, can be extended up to 24% more than that of single level approach.

Figure 6 shows comparison of Genetic algorithm based approach with A-Star algorithm based approach, ASEER. For data gathering without aggregation, GA based approach has been suggested in [4].

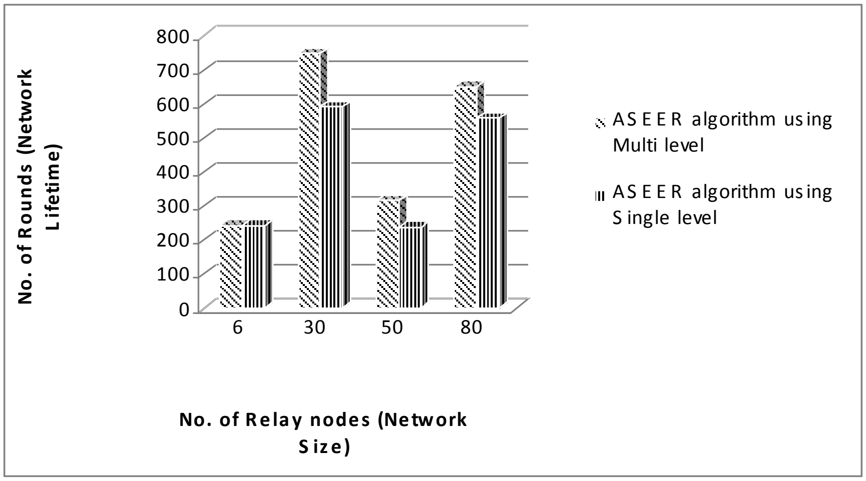


Figure 5 : Comparison using Multi level and single level approach

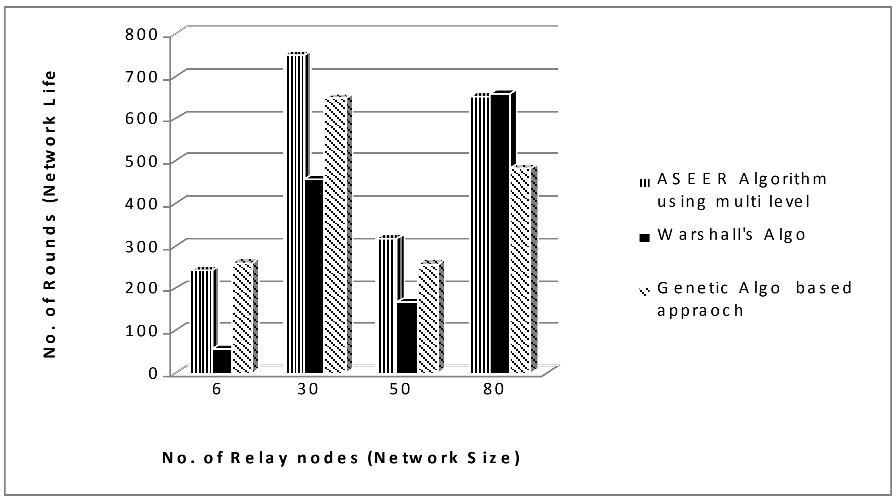


Figure 6 : Comparison of ASEER algorithm, GA based approach and Warshall's algorithm

It can be seen from the figure 6 that, using ASEER algorithm, network lifetime is extended. In most of the cases it is extended around 15% than that of Genetic algorithm based approach and it is extended to more than 40% than that of Warshall's algorithm.

6. CONCLUSION

This paper focuses on A-Star algorithm based heuristic routing technique in wireless sensor network. This approach is mainly used to extend lifetime of Wireless Sensor Network. In our model 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.

A technique using Genetic Algorithm (GA) based approach for data gathering without aggregation has been compared with our approach. We have also compared Warshall's algorithm with our approach. ASEER algorithm gives around 15% better result than the GA based approach and around more than 40% better result than Warshall's algorithm. Introducing a pre-defined level of minimum energy (*Level1*) helps to protect a sensor node from draining out earlier and thus, enhance overall life of the wireless sensor network.

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