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An Efficient Routing Method for Lifetime Enhancement in Wireless Sensor Network using Fuzzy Approach and A-Star Algorithm

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Abstract*—Today, Wireless Sensor network are used in many applications to gather sensitive information which is then forwarded to an analysis centre. This paper proposes a new routing method for WSNs to extend network lifetime using combination of fuzzy approach and an A-star algorithm. The proposed method is to determine an optimal routing path from the source to the destination by favoring the highest remaining battery power, minimum number of hops, and minimum traffic loads. This proposed approach is compared with A-star search algorithm and fuzzy approach using the same routing criteria in terms of energy consumption, residual energy etc. The effectiveness of proposed method is measure in terms of throughput, packet delivery ratio and average energy consumption. Simulations for this work are carried out over the NS2 simulator.

***Key Word* — A-star algorithm, fuzzy approach, network lifetime, WSN**

I. INTRODUCTION

Recently, we have studied the many recent routing protocols for wireless sensor networks with different goals. The problem with many routing 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. Hence to overcome this problem recently the new method was presented in [1]. In [1], the proposed method seeks to investigate the problems of balancing energy consumption and maximization of network lifetime for WSNs. However this proposed method in [1] has not be evaluated against the network scalability as well as network routing performances, hence this allows us to do the further research in this same area.

This proposed approach is compared with A-star search algorithm and fuzzy approach using the same routing mechanism in terms of energy consumption. In wireless Sensor network 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]. Fig. 1 shows the schematic diagram of components inside a typical sensor node that comprises of sensing, processing, transmission, mobilizes, position finding system and power units. It also shows the communication architecture of a WSN. Each sensor node makes its decisions based on its mission, the information it currently has, knowledge of its computing, communication, and energy resources. 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].

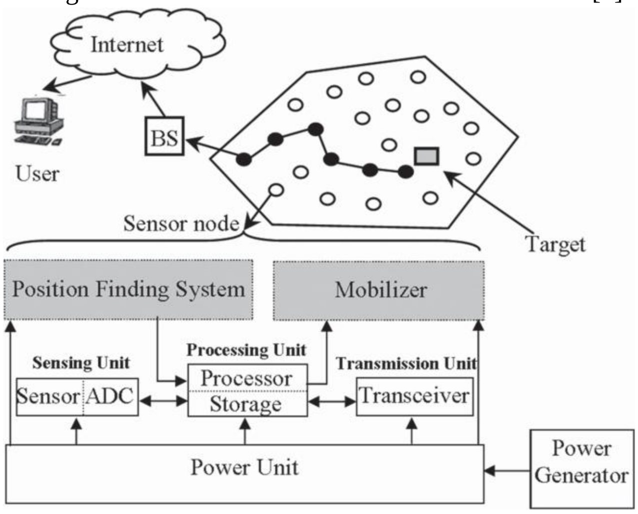

Fig 1. Component of Sensor node

Due to limitations in the range in wireless communication 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 of utmost importance in power-constrained data-gathering sensor networks. Energy consumption should be well managed to maximize the network lifetime. Unbalanced energy consumption is an inherent problem in WSNs characterized by the multi-hop routing and many-to-one traffic pattern. The problem with many routing 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, in this paper, the proposed method seeks to investigate the problems of balancing energy consumption and maximization of network lifetime for WSNs. In this paper we propose combining features of Fuzzy approach and A-star algorithm to select

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Volume 3, Issue 9, March 2014

the optimal routing path from the source to the destination by favoring the highest remaining battery power, minimum number of hops and minimum traffic loads.

The rest of this paper is organized as follows. Related work, the routing algorithm to maximize the WSN lifetime is in Part II. In Part III, the paper describes in brief about Fuzzy approach and A-star algorithm. The routing model for the proposed routing method is presented in Part IV. Performance evaluation is proposed in Part V. Finally, conclusion and future aspects are in Part VI.

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 maximizing 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 work in [1] proposed an optimal routing and data aggregation scheme for wireless sensor networks. The objective was to maximize the network lifetime by jointly optimizing data aggregation and routing. They adopt a model to integrate data aggregation with the underlying routing scheme and present a smoothing approximation function for the optimization problem. The necessary and sufficient conditions for achieving the optimality are derived and a distributed gradient algorithm was designed accordingly. They show that the proposed scheme can significantly reduce the data traffic and improve the network lifetime. The distributed algorithm can converge to the optimal value efficiently under all networks.

In [2], they have studied the problem of maximizing network lifetime through balancing energy consumption for uniformly deployed data-gathering sensor networks. They formulated the energy consumption balancing problem as an optimal transmitting data distribution problem by combining the ideas of corona-based network division and mixed-routing strategy together with data aggregation. They first proposed a localized zone-based routing scheme that guarantees balanced energy consumption among nodes within each corona.

In [4], they design an Energy-Balanced Routing Protocol (EBRP) by constructing a mixed virtual potential field in terms of depth, energy density, and residual energy. The goal of this basic approach is to force packets to move toward the sink through the dense energy area so as to protect the nodes with relatively low residual energy. To address the routing loop problem emerging in this basic algorithm, enhanced mechanisms are proposed to detect and eliminate loops. The basic algorithm and loop elimination mechanism are first validated through extensive simulation experiments. Finally, the integrated performance of the full potential-based energy-balanced routing algorithm is evaluated through numerous simulations in a random deployed network running event-driven applications, the impact of the parameters on the performance is examined and guidelines for parameter settings are summarized. Our experimental results show that there are significant improvements in energy balance, network lifetime, coverage ratio, and throughput as compared to the commonly used energy-efficient routing algorithm.

In [18] the authors presented Optimal Forwarding by fuzzy Inference Systems (OFFIS) for flat sensor networks. The OFFIS protocol selected the best node from candidate nodes in the forwarding paths by favouring the minimum number of hops, shortest path and maximum remaining battery power, etc. The authors in [19] presented 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.

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 [4], [6]. Fig. 2 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 neighbour.

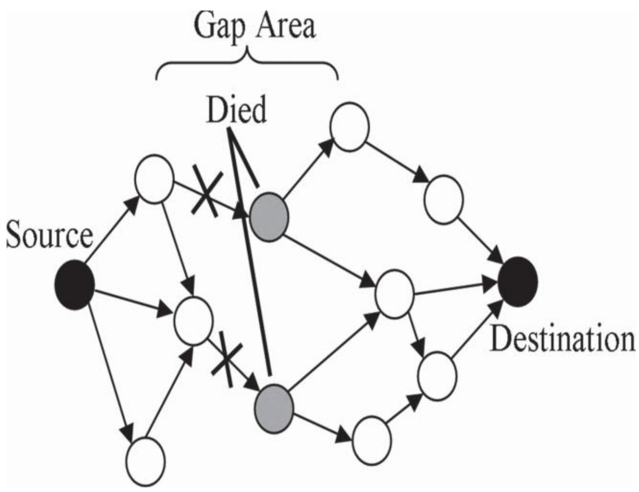

Fig 2 Network partition due to the death of certain nodes

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

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International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 9, March 2014

note that a number of different metrics have been used to prolong the lifetime of the sensor networks.

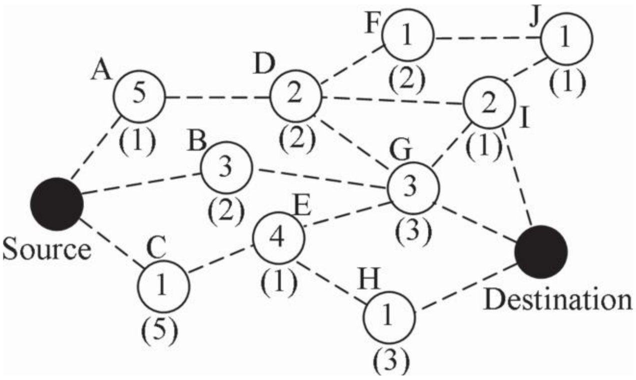

Fig 3 Routing options in a small WSN. The numbers inside the nodes represent the remaining energy and the numbers in parentheses represent the traffic load.

The matrices considered are as follows

1) Remaining Energy (RE): 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.

2) *Minimum Hop (MH)*: 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.

3) *Traffic Load (TL)*: The traffic load (or intensity) of anode is defined as the pending amount of traffic in a node's queue. This includes the application traffic and also the traffic that a node has already committed to forwarding. In the case that concentration of events in some particular sub-areas is more than that of areas, using shortest path will cause implosion along the path. The high traffic load causes a data queue overflow in the sensor nodes, resulting in loss of important information.

III. OVERVIEW OF FUZZY APPROACH AND A-STAR

Following are two approaches that we consider for proposed method

A) Fuzzy Approach

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. Rules are the heart of a fuzzy system and may be provided by experts or can be extracted from numerical data. In either case, the rules that we are interested in can be expressed as a collection of IF THEN statements.

Fuzzy logic analyzes information using fuzzy sets, each of which is represented by a linguistic term such as "*small*," "*medium*," or "*large*." Fuzzy sets allow an object to be a partial member of a set. 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:

$$A = \{(x, \mu_A(x)/x \in X\}. \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

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 ($\mu_A(x)$ −1), it means that input *x* belongs to the set *A* with a high degree, while small membership values ($\mu_A(x)$ −0), indicate that set *A* does not suit input *x* very well.

B) A-Star Algorithm

A-star search algorithm is a widely used graphic searching algorithm. It is also a highly efficient heuristic algorithm used in finding a variable or low cost path. It is considered as one of the best intelligent search algorithms that combines the merits of both depth-first search algorithm and breadth-first algorithm. A-star path searching algorithm uses the evaluation function (usually denoted f (n)) to guide and determine the order in which the search visits nodes in the tree. The evaluation function is given as:

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

where g(n) is the actual cost from the initial node (start node) to node n (i.e. the cost finding of optimal path), h(n) is the estimated cost of the optimal path from node n to the target node (destination node), which depends on the heuristic information of the problem area .

Generally, A-star algorithm maintains two lists, an OPEN list and a CLOSE list. The OPEN list is a priority queue and keeps track of the nodes in it to find out the next node with least evaluation function to pick. The CLOSE list keeps track of nodes that have already been examined. Initially, the OPEN list contains the starting node. When it iterates once, it takes the top of the priority list, and then checks whether it is the goal node (destination node). If so, the algorithm is done. Otherwise, it calculates the evaluation function of all adjacent nodes and adds them to the OPEN list. After the A-star algorithm is completed, it will find a solution if a solution exists. If it doesn't find a solution, then it can guarantee that no such solution exists. A-star

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Volume 3, Issue 9, March 2014

algorithm will find a path with the lowest possible cost. This will depend heavily upon the quality of the cost function and estimates provided. A-star algorithm may be expressed as following:

1) Put the source node *s*0, *f (s*0*)* attached, into the OPEN list. Let the CLOSE list is empty.

2) If the OPEN is empty, exit, and the search is fail.

3) Move out the first node *N* form the OPEN list, which has the smallest *f (.)* in the list, and put it into the CLOSE list; number the node as *n*.

4) If the node *N* is the goal node, the search is finished, *exits*.

5) If the node *N* cannot spread, turn to *step* 2.

6) Spread the node *N*, there will be a group of nodes, all of which are *f (n)* attached; add the nodes to the OPEN list, then turn to *step* 3; Especially, for the gotten nodes in this step, some processing will be done.

a) Examine the OPEN list and the CLOSE list to find whether (some of) the nodes have been included in them. For the nodes that have been included, if they are ancestor node of the node *N*, delete them; If they are not (the ancestor node), delete them too, but for they are spread on the second time, it is needed to review them and find whether the corresponding *f (n)*, the back pointers of the nodes and even those of the corresponding descendant nodes are needed to be changed. The rule of such changing is "*choosing the short path based on f (n)*."

b) For the nodes that have not been included in the OPEN list and the CLOSE list, put them into the OPEN after assigning the back pointer that points to the node N, then based on f(n), sort all the nodes in ascending order.

IV. PROPOSED METHOD

The topology of a WSN is design as a directed graph *G (N, A)*, where *N* is the set of nodes, and *A* is the set of direct links between the nodes. A sink node is responsible for collecting data from all other nodes within its transmission range [5], [9], [10]. The routing schedule is computed by the base station. It calculates optimal routing schedule and broadcasts it. Every node follows this schedule. The process of ***finding*** the optimal path, and ***broadcasting*** it in the network and ***sending*** data from all nodes 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 some criteria of each node. For this, normally it may require the nodes to report their criteria periodically to the base station. The base station can then determine the routing schedule based on this updated information.

The proposed method assumes that: 1) all sensor nodes are randomly distributed in the area and every sensor node is assumed to know its own position as well as that of its neighbors and the sink; 2) all sensor nodes have the same maximum transmission range and the same amount of initial energy; 3) each node has a certain amount of traffic pending in node's queue. The node's queue includes the application traffic and also the traffic that a node has already committed to forward.

One of the important measures of WSN is the network lifetime. For the proposed model, whenever any sensor node runs out of energy, communication links between various sensor nodes and the base station will break. This is considered as the end of the network lifetime.

Since the lifetime of each sensor node depends on energy consumption, it is important to preserve residual energy of these nodes in such a way that overall network lifetime is extended. The primary goal of this paper is to design a protocol that will prolong the lifetime of the WSNs through limiting energy cost as well as equal distribution of energy consumption. To achieve this, we make use of both the Fuzzy approach and A star algorithm. The new method uses all three routing criteria, mentioned in Part II (i.e. highest Remaining Energy, minimum number of Hops and lowest Traffic Load) to select the optimal next hop to this node.

A. Implementation of A-Star Algorithm

In the new routing method, 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.

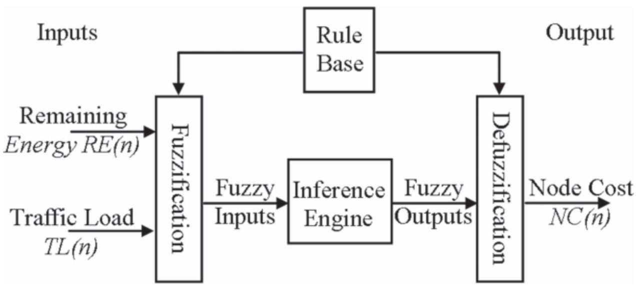

Fig 4 Fuzzy structures with (remaining energy and traffic load) and output (node cost).

The tree node is explored based on its *evaluation function f (n)*. The function we used is given as:

$$f(n) = NC(n) + (1/MH(n)) \quad (3)$$

Where *NC (n)* is the node cost of node *n,* which takes value [0…1], and can be calculated by the fuzzy approach. The fuzzy approach is considered for the remaining energy and the traffic load of node *n* to calculate the optimal cost for node *n*. *MH (n)* is the short distance from node *n* to the base station. As a result, the node *n* that has largest *f (n)* value will be chosen as the optimal node.

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Volume 3, Issue 9, March 2014

B. Implementation of Fuzzy Approach

The goal of the fuzzy part of the proposed protocol is to determine the optimal value of the node cost NC(n) of node n that depends on the remaining energy RE(n) and the traffic load TL(n) of node *n*.

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.

V. PERFORMANCE EVALUATION

To demonstrate the effectiveness of the proposed method in terms of balancing energy consumption and maximizing network lifetime, simulation results of the proposed are compared with those of A-star search algorithm and with those of Fuzzy approach.

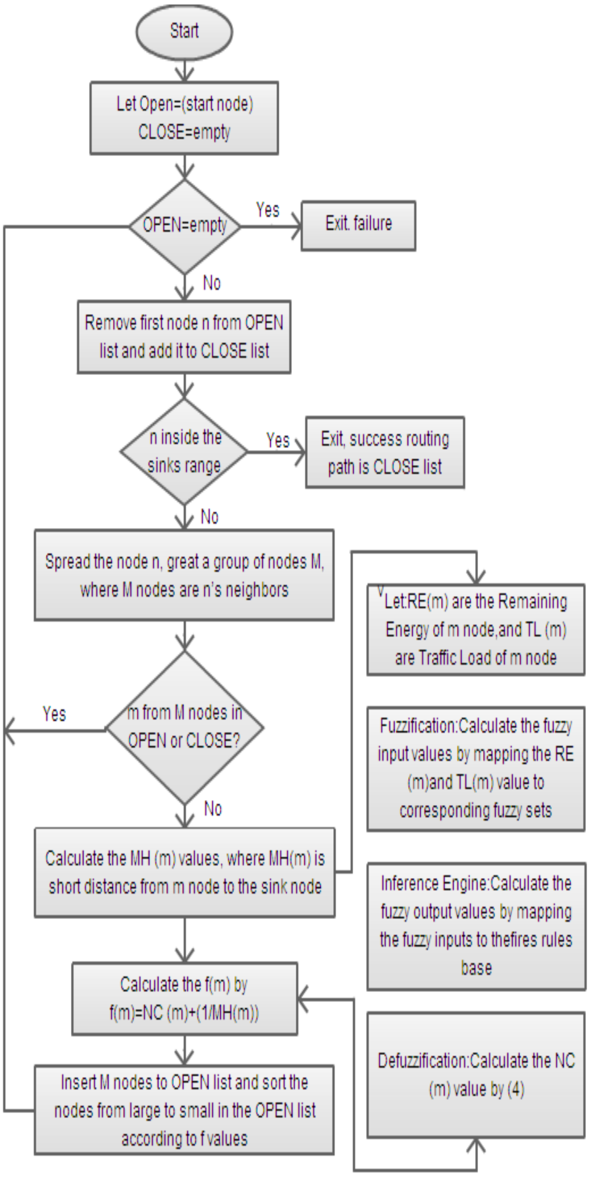

Fig 5 Flowchart of Proposed Algorithm

A. Simulation Setup

The experiments for the evaluation of the proposed scheme have been carried out using the network simulator *ns-2*. Performances of the three protocols are evaluated: (i) A-star Algorithm, (ii) Fuzzy approach (iii) A-star with Fuzzy approach the proposed algorithm. For this we have used Ad-Hoc on demand distance vector (AODV) routing protocol and consider various number of nodes like 20,40,60,80,100. The scenarios developed to carry out the using these parameters (i) Packet Delivery Ratio (ii)End Delay Vs. Number of Sensors (iii) Normalized Routing Overload Vs. Number of Sensors (iv) Throughput Vs. Number of Sensors (v) Energy Vs. Number of Sensors.
From all these result we are able to analyzed effectiveness of proposed method.

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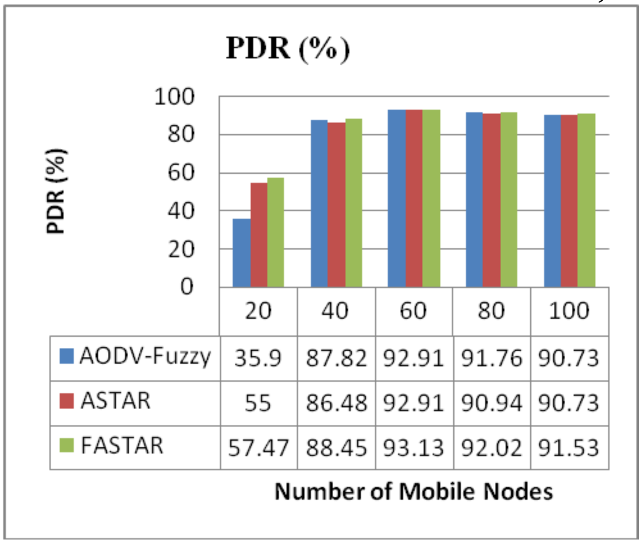


Fig 6 Average Energy Consumption (J)

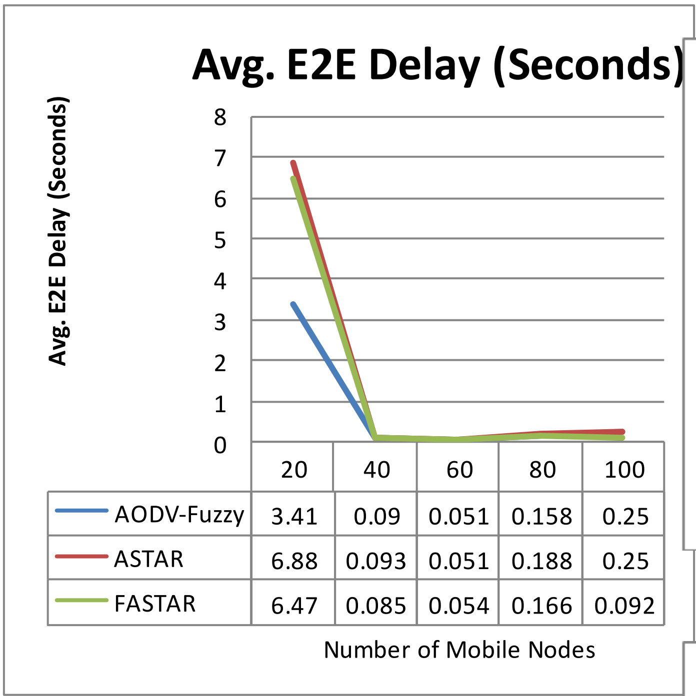


Fig 7 Avg. End to End Delay

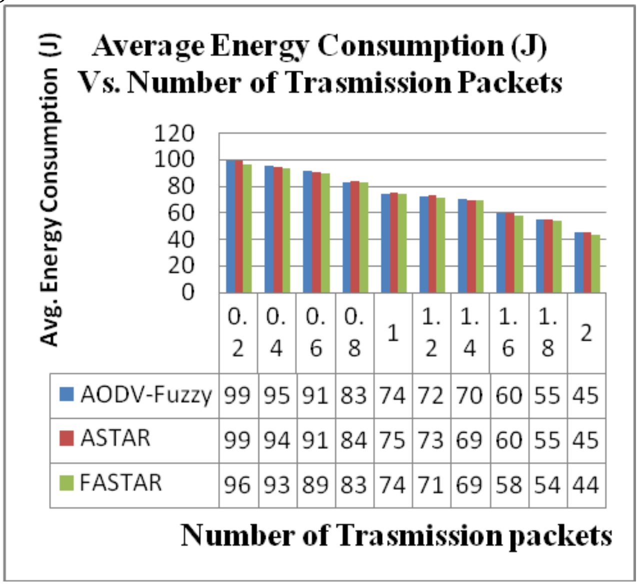


Fig 8 Average Energy Consumption

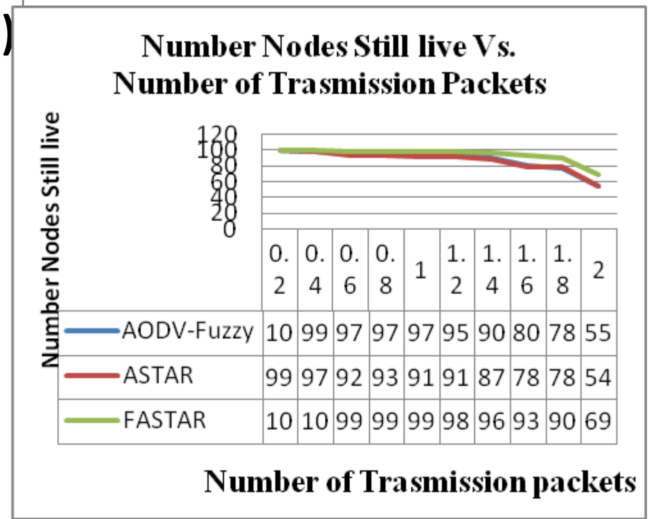
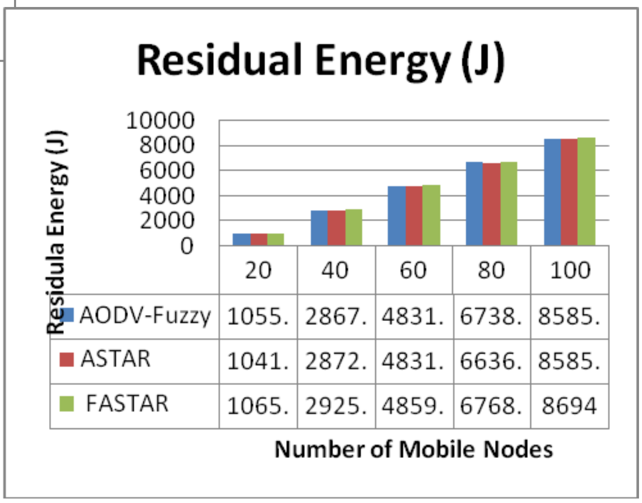


Fig 9 Lifetime in terms of live nodes



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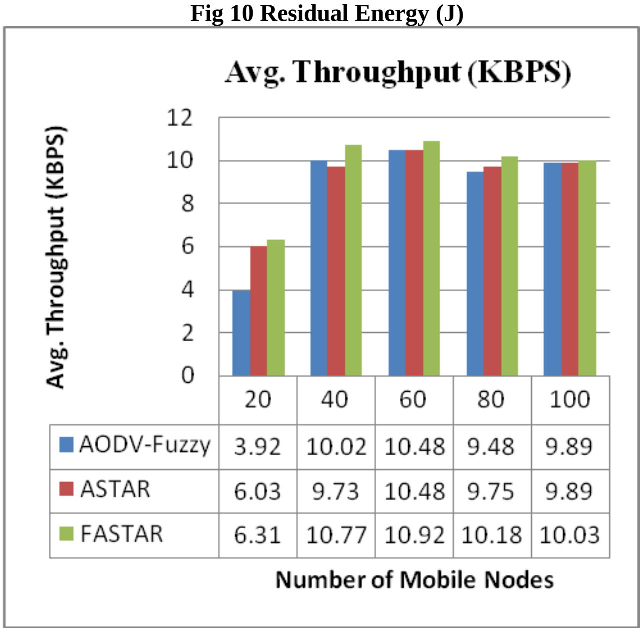
Volume 3, Issue 9, March 2014

Fig 10 Residual Energy (J)



	20	40	60	80	100
AODV-Fuzzy	3.92	10.02	10.48	9.48	9.89
ASTAR	6.03	9.73	10.48	9.75	9.89
FASTAR	6.31	10.77	10.92	10.18	10.03

Fig 11 Average Throughput

VI. Conclusion

In this paper we have conducted a NS2 based simulation study to investigate the performance of proposed method by using AODV protocol. In wireless sensor networks where nodes operate on limited battery energy efficient utilization of the energy is very important. One of the main characteristics of these networks is that the network lifetime is highly related to the route selection. To efficiently route data through transmission path from node to node and to enhance the overall lifetime of the network, we proposed a new algorithm by using a combination of both Fuzzy approach and A-star algorithm. After implementation of fuzzy approach we got result of various parameters like energy (average and residual), throughput, PDR, End to End delay, routing load vs. no. of nodes etc. along with these average energy consumption vs. no. of transmission packets, no of nodes still alive vs. no of transmission packet, Average network remaining energy vs. no. of transmission packets.

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