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Network Lifetime through Link Stability using Fuzzy Logic in Mobile Ad Hoc Network

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Abstract: *Mobile ad hoc networks are more complex wireless networks, which have little or no existing network infrastructure. These networks can be established in a spontaneous manner allowing organizations and network members to work together and communicate, without a fixed communication structure. there are many issues in mobile ad hoc networks like security, mobility, limited bandwidth and many more. So to increase the network lifetime in mobile ad hoc networks here we are considered the residual battery and link stability. In MANET, route is only maintained during short time and mobile nodes are connected with each others having limited battery capacity. Namely, it is very important that we consider Link Stability and Battery Capacity at the same time in MANET. In recent years, much research has been under taken to not only improve the energy efficiency but also to lengthen the network lifetime. Also by using Fuzzy Logic is able to extend network lifetime by reducing power consumption and distributing traffic load centralized into special node. We have used AODV as a basic routing protocol and network simulator 2 for simulation and getting results.*

Keywords: *MANET, Link Stability, Residual Battery, Fuzzy Logic*

I. INTRODUCTION

Mobile Ad-Hoc Network(MANET) is an autonomous system, where nodes/stations are connected with each other through wireless links. There is no restriction on the nodes to join or leave the network, therefore the nodes join or leave freely. Mobile Ad-Hoc network topology is dynamic that can change rapidly because the nodes move freely and can organize themselves randomly. This property of the nodes makes the mobile Ad-Hoc networks unpredictable from the point of view of scalability and topology.

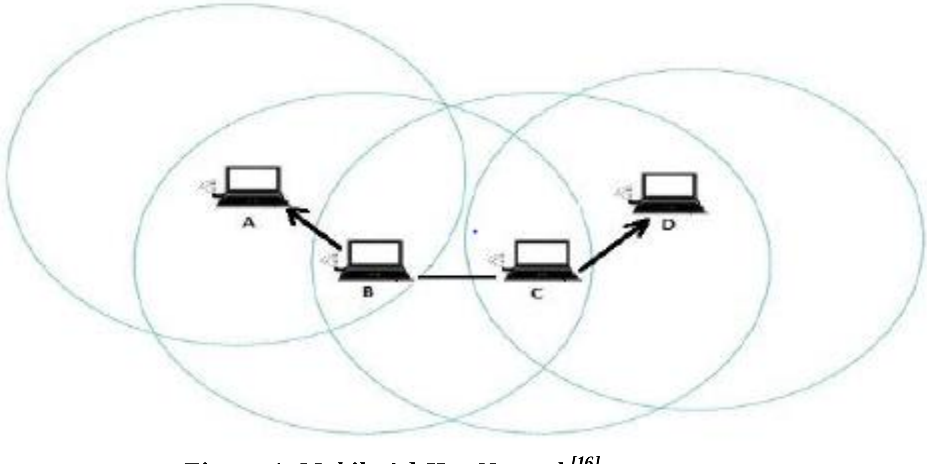


Figure. 1: Mobile Ad-Hoc Network[16]

Nodes are the systems or devices i.e. mobile phone, laptop, personal digital assistance, MP3 player and personal computer that are participating in the network and are mobile. These nodes can act as host/router or both at the same time.

Mobile ad hoc networks differ from existing wired networks because they do not rely on a fixed network infrastructure, such as base stations or mobile switching centres. Instead, network functionality (e.g., routing, mobility management, etc.) is adopted by the nodes themselves. When using a multi-hoping routing protocol, mobile nodes within each other's radio range communicate directly via wireless links. However the nodes that are far apart depend on the other nodes to relay the message in a multi-hop fashion.

The limitations and inefficiency of MANET are unpredictable link properties, node mobility and limited battery life. Wireless media is very unpredictable. Signal propagation faces difficulties such as signal fading, interference, and multipath cancellation. All these properties make measures such as bandwidth and delay of a wireless link unpredictable. Mobility of the nodes creates a dynamic network topology. Links will be dynamically formed when two nodes come into the transmission range of each other and are torn down when they move out of range. Mobile devices generally depend on finite battery sources. Resource allocation must consider residual battery power and rate of battery consumption corresponding to resource utilization.

The rest of the paper is as follows, In section 2 we give related work as an overview of Link Stability and Fuzzy logic in mobile ad hoc network. In Section 3 the proposed work is described. Section 4 describes Simulation results and finally Section 5 describes the conclusion and future work of our research work.

II. RELATED WORK

Stability:

Stability can be an important element in the design of routing protocols. Stable routes, also called the long-lived routes, are used to reduce the overhead resulted from route maintenance in ad hoc networks. It reduces route reconstruction that is caused by the link failure, and thus increases network throughput and decreases overhead. Stability can be predicted by the link and the route lifetime based on the nodes' location and movement information proposed in [16]. The routing concept introduced in [16] is to predict the Link Expiration Time (LET) at each hop of the route, which allows the prediction of the Route Expiration Time (RET). RET is defined as the minimum LET of the links composing the route.

The Link Expiration Time[10] between two mobile nodes i(x,y) and j(x,y) is defined by the following equation:

$$LET = \frac{-(a+b) + \sqrt{(a^2+c^2)r^2 - (\mathrm{ad} - \mathrm{bc})}}{a^2 + c^2}$$

[Equ. 1]

Where,

$a = v1\ cos\theta 1\ - v2 \cos\theta 2$
$b = x1 - x2$
$c = v1\ sin\theta 1\ - v2 \sin\theta 2$
$d = y1 - y2$

Here, $\theta 1$,v1, $\theta 2$ and v2 are the movement directions and speed of node i and j respectively.

Link stability indicates how stable the link is and how long it can support communication between two nodes. We can estimate link stability using many parameters. Signal strength was used in SSA[1].
Pilot signal is used to estimate link stability between nodes in ABR. If a node receives continuous pilot signals from a neighbour node and the number of continuous signal exceeds a certain limit, it considers a link to the neighbour node as stable link[4].

There are various types of restrictions for stability. The main restriction is the frequent change of network topology as nodes are mobile and confined energy of the batteries. In MANET, route is only maintained during short time and mobile nodes are connected with each others having limited battery capacity. Shortest path route has short lifetime especially in highly dense ad-hoc wireless networks due to the edge effect[4].

Fuzzy Logic in MANET[17]:

Routing and related resource allocation issues present special challenges in ad hoc networks. Typically, every node in an ad hoc network serves as a router for other nodes, and paths from source to destination often require multiple hops. Compared to wired networks, wireless ad hoc networks have less bandwidth, longer paths, and less stable connectivity, all of which render routing protocols from wired networks less suitable for the wireless world.
In Mobile Ad hoc Networks that applies fuzzy logic to differentiated resource allocation, considering traffic importance and network state. Messages are routed over zero or more maximally disjoint paths to the destination: important packets

may be forwarded redundantly over multiple disjoint paths for increased reliability, while less important traffic may be suppressed at the source.

Fuzzy control is applied to the dynamic allocation of network bandwidth based on message precedence and network status, with a goal of increasing the precedence-weighted performance of MANETs carrying multiple-precedence traffic.

Fuzzy routing protocols consider network status as one factor in making rout- ing decisions. Network status ranges from Excellent (low traffic, less mobility, no congestion) to Poor (high traffic, high mobility, and congested queues). The Fuzzy Routing algorithm monitors the congestion status of active routes and feeds the net- work status to the Fuzzy Logic Controller in order to make the best routing decision.

The field of fuzzy sets and logic is a rigorous mathematical one, and provides an effective tool for modelling the uncertainty in human reasoning. In fuzzy logic, the knowledge of experts is modelled by linguistic rules represented in the form of IF-THEN logic.

Fuzzy Inference System and Fuzzy Controller:

In Control systems, the inputs to the systems are the error and the change in the error of the feedback loop, while the output is the control action. Fuzzy logic based controllers are popular control systems. The general architecture of a fuzzy controller is depicted in Figure 2. Fuzzy controllers are knowledge based, where knowledge is defined by fuzzy IF-THEN rules. The core of a fuzzy controller is an FIS, in which the data flow involves fuzzification, Knowledge based evaluation and defuzzification.

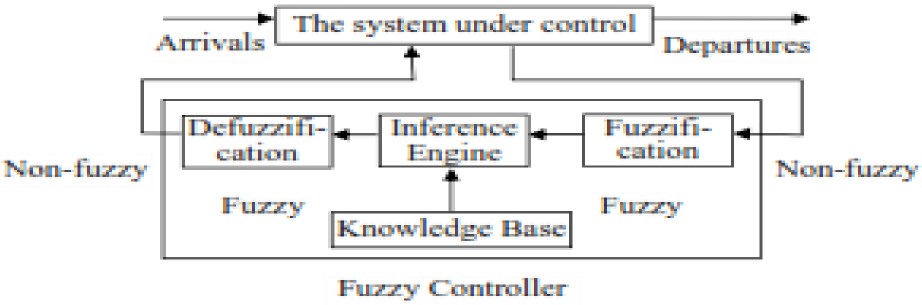


Figure 2. The Fuzzy Controller [12]

The difference between the logic is that fuzzy set theory provides a form to represent uncertainties, that is, it accepts conditions partially true or partially false. Fuzzy logic is the best logic to treat random uncertainty. There are generally two kinds of fuzzy logic controllers. One is feedback controller, which is not suitable for the high performance communication networks. Another one, which is shown in Figure 2. The output of the fuzzy logic controller in Figure 2 is used to tune the controlled system's parameters based on the state of the system. This control mechanism is different from the conventional feedback control and considered as an adaptive control. The specific features of the fuzzy controller depend on the model under control and performance measurement. However, in principle, in the fuzzy controller we explore the system relationship rules and subsequently develop the optimal fuzzy control rules as well as a knowledge base.

In an FIS, the knowledge base is comprised of the fuzzy rule base and the database. The database contains the linguistic term sets considered in the linguistic rules and the MFs defining the semantics of the linguistics variables and information about domains. The rule base contains a collection of linguistic rules. The fuzzification process collects the inputs and then converts them into linguistic values or fuzzy sets. The decision logic, called fuzzy inference engine, generates output from the inputs, and finally the defuzzification process produces a crisp output for control action.

III. PROPOSED WORK

In this section we are proposing a method to increase and extend the network lifetime using link stability, residual battery and distance of a node by applying fuzzy logic between these parameters.

Mobile Ad-hoc Network(MANET) uses base station system which is compo- sed of a group of mobile and wireless nodes. There are various types of restrictions. The main restrictionis the frequent change of network topology and confined energy of the batteries. In MANET, route is only maintained during short time and mobile nodes are connected with each others having limited battery capacity. Namely, it is very important that we consider Link Stability and Battery Capacity at the same time in MANET.

Routing protocols in MANET are categorized into Table-Driven and On-Demand protocol. In the Table-Driven protocol, each node must update routing table whenever network topology is changed. For that reason, transmission overhead about a control packet is increased. In the On- Demand protocol, (DSR, AODV, etc.), a transmitter sets a route only if needed, so the overhead due to the control packet is reduced. Since the DSR and AODV use as a metric only hop distance between nodes, the end-to-end distance may be short. But the lifetime of network is shortened by inefficient consumption of battery.

The Fuzzy AODV Protocol(FAODV) is based on AODV(Ad hoc On-demand Distance Vector Routing), It considers distance among neighbour nodes, Residual Battery Capacity and Link Stability. It is able to increase the Lifetime of Network through distribute the traffic load.

Link Expiration Time(LET)[10]:

From Equ. 1, if v1,v2,θ1,θ2 are node velocity and movement of node.
Then Link is active between two node if d(transmission range between two nodes) can be calculated ,
Distance between two nodes on X-axis after time 't'=

$$D_x = [x1 - x2] + [v1\, cos\theta 1 \;\; - v2 \cos\theta 2]t$$

Distance between two nodes on Y-axis after time 't'=

$$D_y = [y1 - y2] + [v1\, sin\theta 1 \;\; - v2 \sin\theta 2]t$$

So, $d = \sqrt{{D_x}^2 + {D_y}^2} < r = \sqrt{(b+at)^2 + (d+ct)^2} = (a^2 + c^2)t^2 + 2(ab + cd)t + (b^2 + d^2 - r^2)$

By solving this Equ. we can get the link expiration time between two node.

Fuzzy Based Routing:

Fuzzy logic is applied in control systems either to improve performance or to avoid difficult mathematical problems. We here apply fuzzy control to MANET routing.

Fuzzy logic rules are used in FAODV to determine the node to route messages through High, Very High, Low and Very Low Value in a Network. These rules depend on the energy value and the signal strength of a node in the network.

The Fuzzy Logic Controller has two inputs: Energy Value and Signal Strength of a node, and one output: the routing decision. The rules are given below,

Fuzzy Logic System Rules:

The rules are as follows:

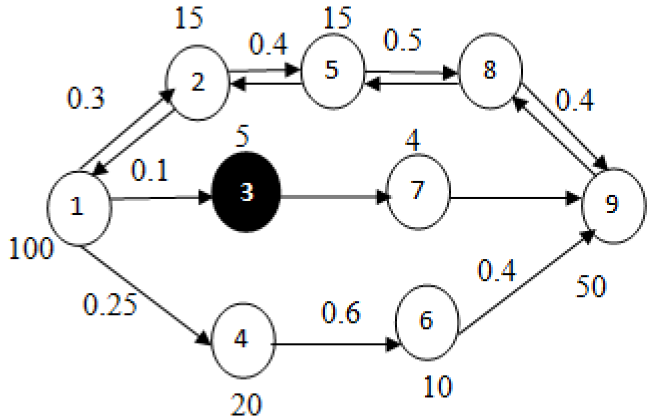
- **Rule1 :** IF energy value is high and signal strength value is high THEN reliable value is very very high.
- **Rule2:** IF energy value is high signal strength is medium THEN reliable value is very high.
- **Rule3:** IF energy value is medium and signal strength is high THEN reliable value is high.
- **Rule4:** IF energy value is medium and signal strength is medium THEN reliable value is medium.
- **Rule5:** IF energy value is medium and signal strength is low THEN reliable value is low.
- **Rule6:** IF energy value is low and signal strength is anything THEN reliable value is very low.

Route Request:

A source node starts to flood RREQ packets to its neighbouring nodes in MANET until they arrive at their destination node. Each RREQ consists of source id, destination id, energy value, X- coordinates, Y- Coordinates and velocity of nodes along the path to calculate the Link Expiration Time(LET) of a node from (Equ. 1).

If the LET of a node is greater than the given threshold value of LET it will choose that path for RREQ packets. LET value of each node is calculated along the path to the destination node.
In below example source node 1 send route request to destination node 9 with help of intermediate nodes. Intermediate node receive the RREQ from previous node and compute the Link Expiration time and check LET with predefine Threshold if it is greater than threshold than forward the RREQ to the next node else drop the RREQ. In this example

when node 3 receive RREQ it check with predefine LET threshold(=0.2) so node 3 can not forward the RREQ to the next node.



For selection of a Destination node, the fuzzy logic system rules will applied to each RREQ packet Residual energy and Signal Strength values and the RREQ packet which has maximum reliable value can send the packets to the destination node.

Route Reply:

At destination node, the RREQ packets comes from different routes wait for some time interval and the destination node will sends a route reply(RREP) packet to the path which has maximum reliable value getting from given fuzzy rules

Route Maintenance:

During transmission of data packet, when one of node is moved or turned off, previous node transmits an RERR(Route Error) message and then transmits data via an alternative route. FAODV reserves an alternative route when route is broken to use. Because FAODV knows not only Signal Strength but also Residual Battery. So it is able to reserve the path that is a good condition of Signal Strength or Residual Battery.

IV. SIMULATION AND PERFORMANCE EVALUATION

This section compares the performance of FAODV with the existing protocol through NS-2. We assume that energy consumption in idle mode is ignored and each node operates in a non-promiscuous mode. The simulation environment is as follows:

Parameter	Value
Simulator	NS-2 version 2.35
Simulation Time	300s
Number of nodes	10 to 100
Routing Protocol	AODV
Traffic Model	CBR
Packet size	512 bytes
Terrain	300m x 300m
Speed	5 to 25 m/s
Transmission Range	50m
Mobility Model	Random Waypoint Model

Table 1. Simulation Parameters

Packet Delievery Ratio(PDR):

PDR is the ratio of the number of data packets successfully delivered to the destinations to those generated by CBR sources. From Figure 3, we find that when the number of nodes are minimum i.e. 20, DSR has highest PDR. When the number of nodes are between 20 and 75; the PDR for DSR it decreases while it almost remains constant for AODV and FAODV. In Figure 3 we can see that as No. of Nodes increase the Packet Delivery Ratio also decreases significantly. So by applying our proposed algorithm FAODV that is Fuzzy AODV the Packet Delivery Ratio increases and gives the better results against the normal AODV and DSR by maintaining the stable route in consideration of Residual Battery and Signal Strength.

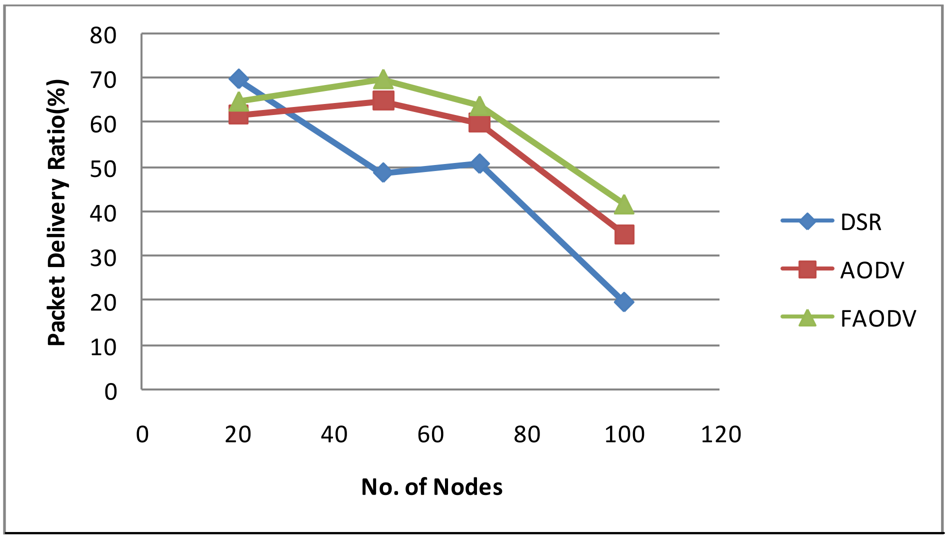


Figure 3. Packet Delivery Ratio v/s No. of Nodes

End to End Delay:

It is the average time from the beginning of a packet transmission at a source node until packet delivery to a destination. This includes delays caused by buffering of data packets during route discovery, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times. Now calculating the Fuzzy Logic and applying it in a routing may consume some time so it can affect the End to End Delay of the network and the End to End Delay might be more than normal AODV and DSR as it will consume some time to find the optimum path. We can see from the Figure 4 that However, DSR has highest End-to-End delay than AODV and FAODV.

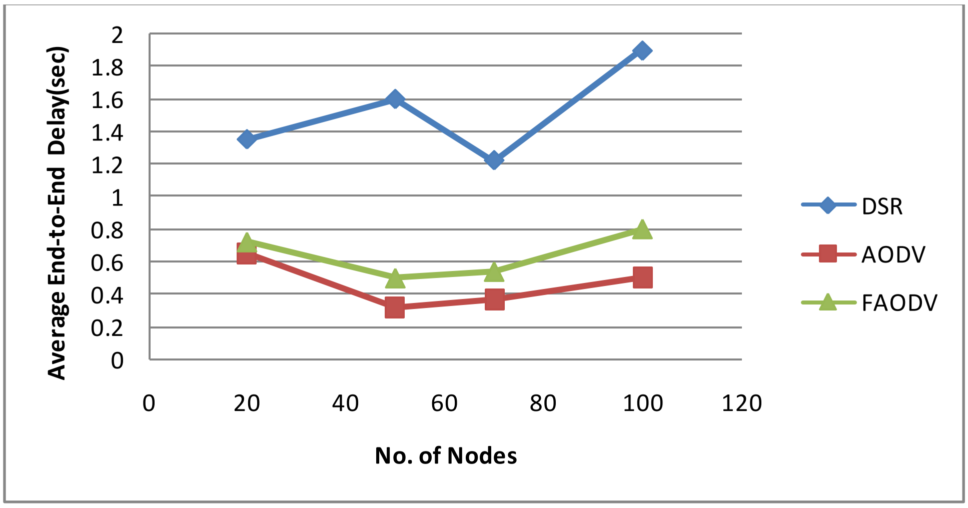


Figure 4. Average End to End Delay v/s No. of Nodes

Remaining Energy:

In Figure 5 the Average Remaining Energy is described against No. of Nodes. From the Figure we can see that our proposed technique has better results against the normal AODV and DSR routing protocols. FAODV considers both Residual Battery and Signal Strength allows balanced battery consumption. The Average Remaining Energy of the network is better in FAODV than normal AODV and DSR.

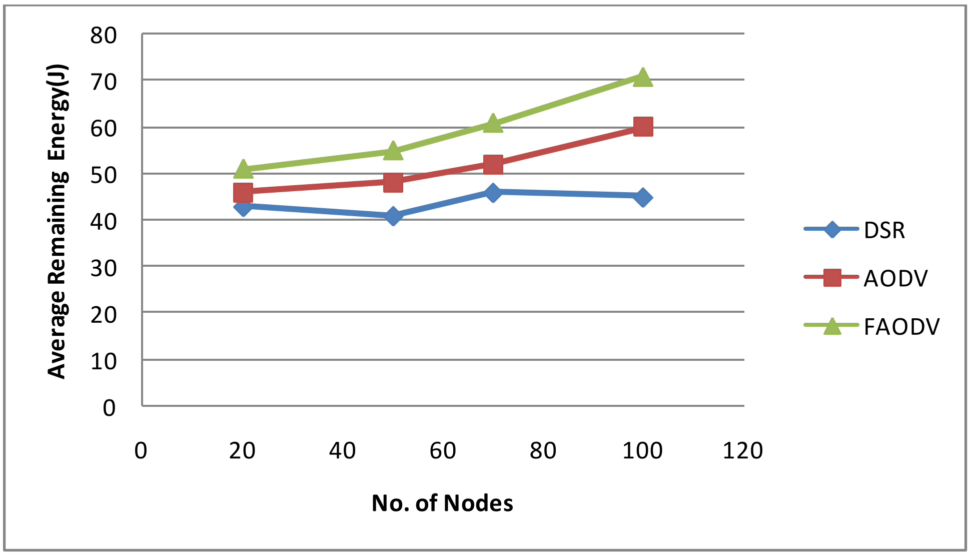


Figure 5. Average Remaining Energy v/s No. of Nodes

Throughput:

This represents the number of packets received by the destination within a given Time Interval. It is a measure of effectiveness of a routing protocol. From Figure 6 it is observed that in low network size, DSR gives highest throughput. As the network size increases, throughput for AODV becomes highest among the three protocols; while the performance of DSR decreases and becomes lowest. Overall when comparing the routing throughput for each of the protocols, AODV has the highest throughput and DSR has the lowest throughput. In Figure 6 the Average Throughput against the No. of Nodes is described. From the Figure we can see that the Throughput of the AODV is more than the FAODV and DSR.

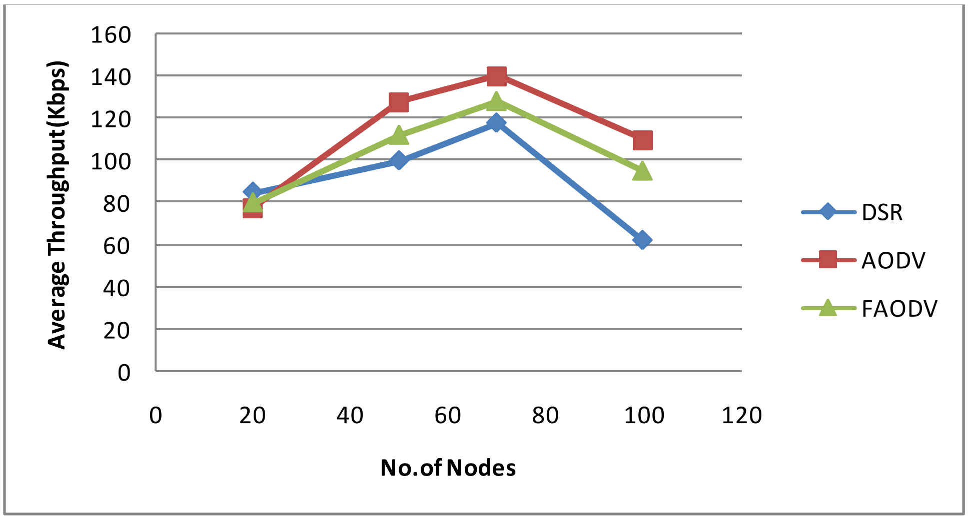


Figure 6. Average Throughput v/s No. of Nodes

V. CONCLUSION & FUTURE WORK

From results we can conclude that our proposed protocol FAODV works well in against the normal AODV protocol. By applying Link Stability we ensures the better Packet Delivery Ratio of the network and using Fuzzy Logic we ensures the energy aware routing in the network. From the results we can see that the Energy Consumption is less in our proposed algorithm and the Average Remaining Energy is more as compared to normal AODV. But for that the End to End Delay is somewhat compromised as to apply Fuzzy Logic at the receiver end.

In future work we will apply some QOS parameters in the Fuzzy Logic to get the better End to End Delay also. For example we can use the QOS parameter End to End Delay with our Fuzzy Rules to get better End to End Delay or we can use bandwidth to ensure the better Throughput of the network.

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