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A Fuzzy-Genetic Based Approach for Improving OLSR Routing Protocol in Mobile Adhoc Networks

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Abstract: One of the MANET routing protocol, Optimized Link State Routing (OLSR) is based on link state routing protocol. In OLSR, the flooding of packets is optimized by using multipoint relay (MPR) nodes. The MPR nodes have the responsibility for controlling and forwarding traffic in the network. The efficiency of the OLSR protocol is based on the selected MPRs. So, it is essential to select the nodes possessing certain quality as MPR nodes in the network. In this paper, MPR selection is achieved using Fuzzy Logic based on the metrics lifetime, stability and buffer limit of the nodes. Then, the path to be established from source to destination through the selected MPRs is optimized using genetic algorithm. By using quality MPR, the efficiency of the OLSR routing protocol is improved and is verified by simulation.

Key words: Fuzzy-Logic · Genetic algorithm · MANET · MPR · OLSR · Routing

INTRODUCTION

A network without any fixed infrastructure, non-centralized, self-configuring and having dynamic topology is known as Mobile Ad hoc Network (MANET). Due to lack of centralized coordination in MANET, each node plays roles like router as well as end node. Due to the dynamic topology and battery power constraints, the routing protocols developed for the wired network cannot be employed directly for the MANET. Many researchers have proposed a variety of routing protocols for MANET which are majorly classified as proactive and reactive.

The Optimized Link State Routing (OLSR) is one of the proactive routing protocols developed for MANET. The main concept of the OLSR is based on link state routing algorithm. In link state routing algorithm, each node floods link state packets to all other nodes in the network. But in the OLSR, certain nodes called as Multi Point Relay (MPR) nodes are only involved in transmission of link state packets. For any node ‘x’ in the network, a set of MPR nodes, say, MPR(x), are selected from the 1-hop neighbors of the node ‘x’. The MPR(x) are selected in such a manner that they cover all the 2-hop neighbors of the node ’x’. Since only these MPRs are involved for any communication in the network, the amount of traffic is greatly reduced.

Although the performance of OLSR is greatly influenced by the MPRs, it is very critical to select MPR because the selected MPRs determines various properties of the network like the logical topology, routing path, protocol overhead, delivery of broadcast and multicast packets. But, the existing OLSR standard does not consider the quality of the nodes in the selection of MPRs. Only simple heuristic is applied. Since the overall performance of the OLSR protocol is mainly dominated by MPRs, it is very essential to consider the metrics like the mobility, energy level and buffer limit of each node in the selection of MPRs.

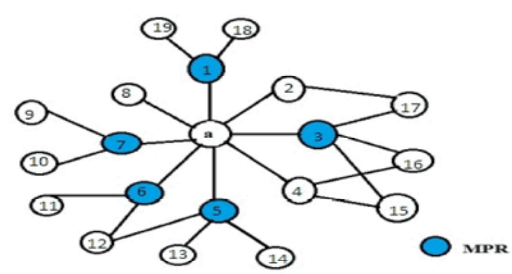

Fig. 1: OLSR protocol with selected MPRs

As in Figure 1 the color nodes represents the selected MPRs of the node ‘a’. These MPRs cover all 2-hop neighbors of node ‘a’. Any multi-hop communication

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between the node 'a' and the rest of the nodes in the network can be achieved only by using these MPR nodes.

Fuzzy logic is one of the Soft Computing (SC) techniques that have been widely used in engineering disciplines. Fuzzy Logic can be applied for the problems having the uncertainty, partial truth and that involves approximation of several metrics. The role model for SC technique is based on human mind. The fuzzy theory constructs a linguistic variable that can be assigned values like high, low, medium, tall and many to enable appropriate human reasoning capabilities.

In fuzzy systems, values are indicated by a number ranging from 0 to 1. Depending upon the linguistic variables, a number of fuzzy rules are formed. The fuzzy systems [1] convert these rules to their mathematical equivalents. In the proposed work, Fuzzy Logic is applied to determine the each node quality that will be utilized in selection of Quality-MPRs (QMPRs). Finding efficient path between any two nodes in large MANET is NP-Hard problem. In such a scenario, Genetic algorithm (GA) [2, 3] can be used to find out the best path from source to destination through the QMPR nodes.

Preliminary

OLSR Routing Protocol: The OLSR protocol [4] is one kind of proactive routing protocol that propagate the link state information with the help of MPR nodes.
Compare to Link-State Routing, OLSR is different in the following ways:

- The size of control packets are reduced
- The amount of flooding are reduced since the link state packets are forwarded only through MPRs.

The MPR nodes in OLSR protocol plays a major role because they provide a solution to reduce the flooding of packets in the network, while transferring some messages to every node in the network. Each node in the network shares the information about set of links with MPR nodes only. The efficiency of the OLSR is based on MPR node. So it is mandatory to give more importance in selecting MPR nodes.

Hakim Badis *et al*. [5] proposed a Quality of Service (QoS) routing protocol for OLSR protocol. Munaretto *et al*. [6] designed a quality OLSR protocol by adding parameters like delay and bandwidth to the existing OLSR. Amir Qayyum *et al*. [7] presented few heuristics to select the MPR nodes in mobile wireless environment. Takeaki Koga *et al*. [8] proposed three heuristics for highly efficient way for selecting MPRs in link state routing protocol. Sreekanth *et al*. [9] discussed about importance of metrics to be considered in MANET routing.

Metrics Selection for the Proposed Work: To implement Quality MPR [10], three metric have been carefully taken which are node's lifetime, stability and its buffer limit. These metrics plays an important role and responsible to elect the best nodes from the MPR set as Quality MPR. If a node is having enough lifetime and moderate buffer limit and not stable means, then it leads to higher route breakages. So, all these three metrics are very important to select the best node as MPR.

Fuzzy Inference System (FIS): Zadeh invented the concept of Fuzzy Logic. Human beings are always taking the decisions based on rules. The fuzzy machines imitate the behaviour of human beings. In FIS [11], the decisions are represented by fuzzy sets and rules are represented by fuzzy rules.

The proposed work employed Fuzzy Logic (FL) [12, 13] technique for the selection of Quality MPR nodes in the OLSR protocol. The MPRs are selected using the Linguistics variables like node's lifetime, stability and its buffer limit. The possible values assigned for these variables are low, medium and high. Using these 3 variables, 27 fuzzy rules are formed. Fuzzy theory is based on the fuzzy sets. Each fuzzy set is characterized by a membership function (MF) which actually associates each element in the fuzzy set to a real number in the interval [0, 1]. The triangular and trapezoidal are the famous MF formed with straight lines. Interpretation of the if-then rule involves fuzzification of the input and applying the suitable fuzzy operators.

Consider X is a set of objects and the element 'x' belongs to X. A fuzzy set F in X that can be defined as a set of ordered pairs.

$$A = \{(x, \mu F(x)) | x \in X\} \quad (1)$$

As given in Equation 1, μF(x) is the membership function (MF) for the fuzzy set F which maps all the elements of X to a value in the interval 0 and 1.

Proposed Work

Fis Based Quality MPR Selection: In OLSR, only simple heuristic is applied in selecting MPR set of a node 'x' (i.e) the selected MPRs should cover all the 2-hop neighbors of the node 'x'. Unfortunately, the MPR selected by this approach may not be expected as quality one. Since the

MPR plays as the backbone for OLSR routing, it is essential to consider the quality of the nodes which are selected as MPRs.

It is better to evaluate all the other factors (lifetime, stability, buffer limit, delay etc.) related to the node before selecting it as a MPR.

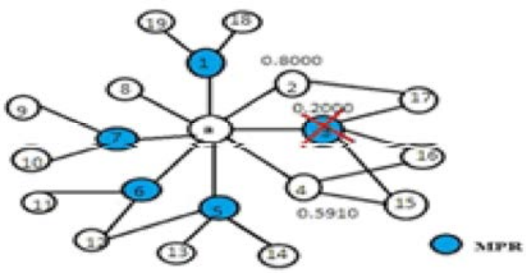

Fig. 2: MPR Selection in OLSR

For example, as in figure 2, the blue color nodes are the set of MPRs selected in the OLSR for the given dynamic MANET. The energy level of the node 2, 3 and node 4 are also shown. According to OLSR, node 3 is selected as MPR because it covers the 2-hop neighbour nodes {15, 16, 17} of node 'a'. Since the energy level of node 3 is very low, the communication established via node 3 will be broken very quickly. But as in figure 3, if the nodes {2 and 4} having more energy are selected as MPRs then, the route lifetime will be extended than existing OLSR.

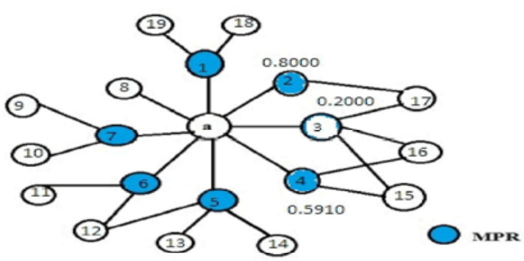

Fig. 3: Quality MPR Selection in proposed System

In proposed system FL approach is predicting the Quality MPRs from the participating nodes. The definition of the various metrics used in predicting the MPRs are discussed as follows:

- The lifetime of a node N at the time period 't' is estimated as:

$$LT_{N(t)} = RE_{N(t)} / ED_{N(t)} \quad (2)$$

where,
$RE_{N(t)}$: the residual energy of the node N at time 't' $ED_{N(t)}$: the energy depletion rate of the node N at time 't'.

- The stability of a node N at the time period 't' in the network is measured by,

$$ST_{N(t)} = \beta_a \frac{N\_OUT(t)}{N(t-\Delta t)} + \beta_b \frac{N\_IN(t)}{N(t)} \quad (3)$$

where
N_OUT(*t*): No. of nodes broken their link with the node N during the time interval [t, t+Δt]
N_IN(*t*): No. of nodes established their link newly with N during the time interval [t, t+Δt]
N(*t*): No. of nodes that are retained their link with the node N during the time interval [t, t+Δt]
β_a, β_b: Constant factors

- Since the MPRs act as the routers for all communication, their buffer limit (BL) also considered.

Using the aforementioned metrics, the probability of a node N to be chosen as Quality MPR is given as follow:

$$Q_f(N) = F\,[\,LT(N), ST(N), BL(N)] \quad (4)$$

As in equation 4, F is the function of *LT(N)*,*ST(N)* and *BL(N)* derived from fuzzy rules given in table 1. The function F actually determines the quality of a node. There are 27 rule are formed by combining the three attributes lifetime (LT), stability (ST) and buffer limit (BL). The interpretation of few of them is as follows:

For any node,
- If LT is Good, ST is Good and BL is Good, then its Quality is Good.
- If LT is Average, ST is Good and BL is Poor, then its Quality is Average.
- If LT is Poor, ST is Poor and BL is Good, then its Quality is Poor.

In the proposed system, a node having higher quality is the best candidate to become as MPR which are known as Quality MPR. Each node 'N' selects the Quality MPRs from its 1-hop neighbour list in such a manner that the selected MPRs should have the Good quality factor and also cover all the 2-hop neighbours of the node N.

After determining the MPR set of each node, if a node needs to find a path to any other node in the network, it uses the MPR set for finding the route. Since this kind of routing is NP-hard problem, the GA is applied to quickly establish the route between any two nodes in the network.

Table 1: Fuzzy Rule Formation

Rules	Life Time (LT)	Stability (ST)	Buffer Limit (BL)	Quality
1	Good	Good	Good	Good
2	Good	Good	Average	Good
3	Good	Good	Poor	Good
4	Good	Average	Good	Good
5	Good	Average	Average	Average
6	Good	Average	Poor	Average
7	Good	Poor	Good	Average
8	Good	Poor	Average	Poor
9	Good	Poor	Poor	Poor
10	Average	Good	Good	Good
11	Average	Good	Average	Average
12	Average	Good	Poor	Average
13	Average	Average	Good	Good
14	Average	Average	Average	Good
15	Average	Average	Poor	Average
16	Average	Poor	Good	Poor
17	Average	Poor	Average	Poor
18	Average	Poor	Poor	Poor
19	Poor	Good	Good	Poor
20	Poor	Good	Average	Poor
21	Poor	Good	Poor	Poor
22	Poor	Average	Good	Poor
23	Poor	Average	Average	Poor
24	Poor	Average	Poor	Poor
25	Poor	Poor	Good	Poor
26	Poor	Poor	Average	Poor
27	Poor	Poor	Poor	Poor

Genetic Algorithm: Meta-heuristics approaches such as GA, ACO and PSO [14, 15] are used to reduce the computational complexity involved in QoS based routing optimization problem in the dynamic environment. The benefit of GA is utilized for constructing efficient route between the source and the destination by using the Quality MPRs.

Priority Based Encoding: The path-encoding algorithm for GA in the proposed work is essentially represented by indirect priority based encoding scheme. The initial population in GA is generated by random manner according to the population size specified. Each of these chromosomes contains priority values for all nodes. A single chromosome which represents a MANET with 10 nodes is represented in Figure 4.

NODE ID	1	2	3	4	5	6	7	8	9	10
PRIORITY	50	19	49	37	25	47	66	92	11	57

Fig. 4: Chromosome representation

The Quality MPRs selected for these nine nodes by using the Fuzzy Logic is given Table 2. In each chromosome in the population, the priority of every node is the network is assigned to some random value. To find out a path from the source node 1 to the destination node 10, the procedure is as follows: Initially, the path between the source (node 1) and the destination (node 10) is assumed as empty. At first, the source node (node 1) is added in the path. Then, the priority of all the Quality MPRs of node 1 is considered. The MPR with highest priority is taken and it is added to the path as the next hop. The Quality MPRs of the node that was recently added in the path is considered to find out the next hop. This procedure is repeated until the destination is reached.

The quality factor identified using fuzzy approach is used to calculate the fitness value. The Quality of all the MPRs which are encountered in the path is added and is assigned as the fitness value of that chromosome. If no path is arrived from source to destination, then its fitness value is assigned to some minimum value (-1). Among all the chromosomes, the one which has the highest fitness value is chosen as the best path.

Table 2: Quality MPR of each node in a given scenario

Nodes	Quality MPR
1	{2,3,9}
2	{1,5,10}
3	{1,4,7,9}
4	{3}
5	{2}
6	{7,8,9}
7	{3,6,10}
8	{6}
9	{1,3,6}
10	{2,7}

For example, the proposed work finds the path between node 1(source) and node 10(destination) as follows: Before begin, the path is empty. When finding the path, the source node is added at first, so now the path is {1}. Finding the suitable path for a given chromosome is explained in Table 3.

Table 3: Finding Path for a chromosome

Node ID	Quality MPRs selected for nodes in column 1	Priority of Quality MPR in column 2	Established Path	Chromosome updation
1	{2,3,9}	{19,49, 11}	{1,3}	{-50,19,-49,37,25, 47, 66,92,11,57}
3	{1,4,7,9}	{-50,37,66, 11}	{1,3,7}	{-50,19,-49,37,25, 47, -66,92,11,57}
7	{3,6,10}	{-49,47, 57}	{1,3,7,10}	{-50,19,-49,37,25, 47, -66,92,11,-57}

Thus, the path obtained is {1, 3, 7, 10}

Fitness Evaluation: Fitness function must accurately measure the quality of the chromosomes in the population. The fitness value of a chromosome is calculated by the sum of the quality factor of all MPRs which are selected for the path to reach the destination. The fitness function is defined as follows:

$$f_i = \sum_{j=1}^{l} Q_f(j) \quad (5)$$

In equation 5,

f_i - Fitness value for i^{th} chromosome
l - Length of the path
$Q_f(f)$ - Quality factor of j^{th} node in the path

Consider the quality obtained for the 10 nodes by the Fuzzy Logic approach is listed in Table 4 below.

Table 4: Quality of each node in the network derived from FL

20.1	33.8	15.3	8.5	40.6	38.9	6.2	39.7	30.7	23.6

The fitness value evaluated for the chromosome in Figure 4 is given in Table 5 as:

Table 5: Fitness value calculation

Path	Fitness value of the path	Fitness Cost
1	20.1	20.1
1,3	20.1+15.3	35.4
1,3,7	20.1+15.3+6.2	41.6
1,3,7,10	20.1+15.3+6.2+23.6	65.2

GA Implementation: Genetic Algorithm is an iterative process that maintains a population of solutions that are candidate solutions to the specific problem. In MANET, the nodes are distributed. Some of the nodes are at better position and can be considered as best nodes (quality MPRs) to reach the destination. We start with the population of randomly generated solution represented as chromosomes and determine how fit it is by applying fitness function. If the solution is good, the problem is terminated, if not the solutions are optimized for a better output by performing GA operations like Selection, Crossover and Mutation. Ultimately only the strongest or fittest node survives and rests are discarded.

Various genetic algorithm operations are as follows:

Selection: The chromosome with maximum fitness value among 'n' chromosome is selected for crossover. Figure 5 shows the population of chromosomes.

Fitness Value

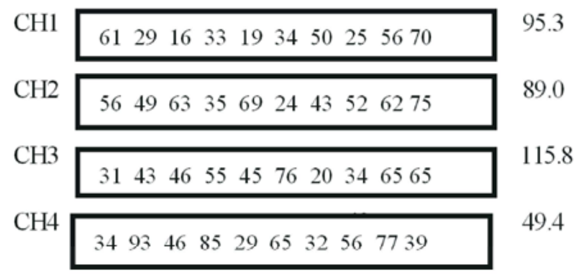

Fig. 5: Population of chromosome with its fitness value

From the Figure 5 the chromosome1 and chromosome3 have best fitness values and they are selected for crossover.

Crossover: New child chromosomes are created by mating parent chromosomes. In Figure 6, single point crossover technique (cross over point = 4) is applied.

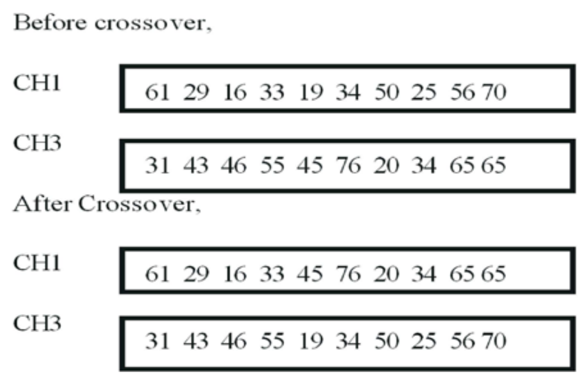

Fig. 6: Crossover example

Mutation: New child chromosomes are produced by randomly changing one or more gene in the chromosomes which is given in Figure 7.

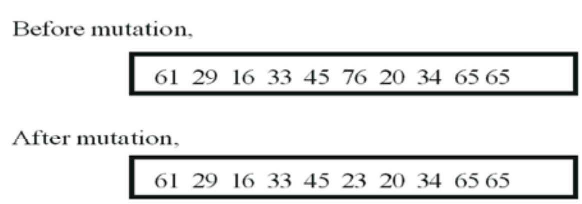

Fig. 7: Mutation example

The Table 6 gives the algorithm for the proposed fuzzy-genetic based approach to find out the path in the network.

Table 6: Proposed fuzzy-genetic algorithm

Step 1:	Initialize a network with 'N' nodes
	having unique identity {1, 2,…n} and assign their positions randomly.
Step 2:	For each node x Δ N(x), calculate the lifetime, stability and buffer limit and these values are fuzzified using fuzzy rules formed to determine the quality of each node as in equation 4.
Step 3:	For each node x Δ N(x), find out 1-hop neighbors N1(x) and 2-hop neighbors N2(x).
Step 4:	For each node x Δ N(x), select certain nodes in N1(x) which are having maximum quality and covers all the nodes in N2(x) as MPR(x).
Step 5:	To find out the best path from source to destination through the selected MPRs, generate initial populations where each chromosome is represented using priority based encoding.
Step 6:	Repeat the steps 7 to 11, until the convergence condition is satisfied.
Step 7:	Evaluate the fitness function of each chromosome from the current population by using the equation 5.
Step 8:	Rank the chromosomes according to their fitness values.
Step 9:	Eliminate the chromosomes having lower fitness values.
Step 10:	Apply single-point crossover operation between the best parents in the current population using the given probability.
Step 11:	Apply the mutation operation with the given probability
Step 12:	Return the best chromosome (best path from source node to destination node)

Experimental Evaluation: The proposed system was implemented using MATLAB 8.1.0 running on Intel core i5 processor with 4 GB RAM capacity and 500 GB hard disk. Operating system used was Windows 7. The simulation setup is shown in Table 7. The parameters considered for the evaluation of the proposed system are

- Packet delivery ratio
- Energy Consumption

Packet Delivery Ratio: Packet Delivery Ratio (PDR) is the ratio between the number of packets received by a destination and the number of packets transmitted by a source.

Table 7: Simulation Setup

Parameters	Specifications
Network Dimension	100 m x 100 m
Number of Nodes	20 to 50
Transmission Range	20 to 50 m
Simulation Time	1000 s
Number of Connections	5
Initial Lifetime	0 to 1 Joules
Transmit Power	0.05 μw
Reception Power	0.02 μw
Traffic Type	Constant Bit Rate
Packet size	1024 bytes
Number of Runs	20

Average Energy Consumption: Energy consumption has been computed by subtracting the residual lifetime from the initial lifetime. This is calculated for all the alive nodes in the network.

RESULTS AND DISCUSSION

The result of the proposed Fuzzy-Genetic based OLSR (FGOLSR) was compared with the OLSR and Fuzzy based OLSR (FOLSR) routing protocol, by showing variations in the transmission range and the number of nodes.

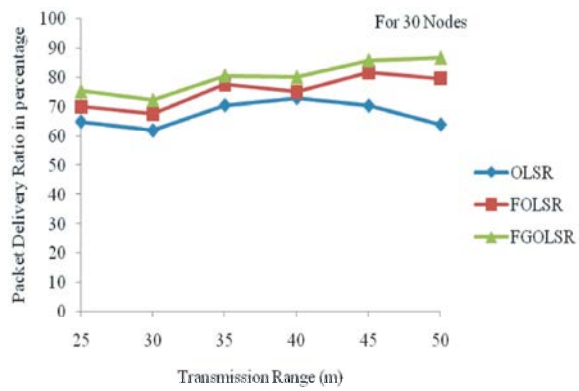

Fig. 8: Packet Delivery Ratio vs. Transmission Range in case of OLSR, FOLSR and FGOLSR in 100m x 100m for 30 Nodes

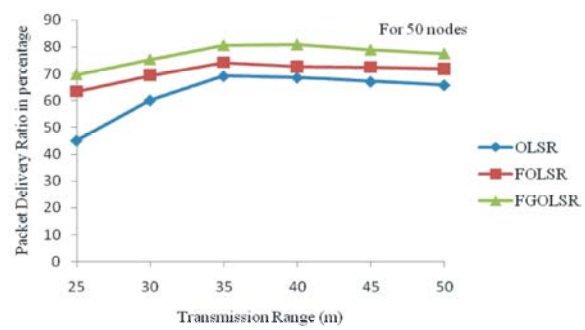

Fig. 9: Packet Delivery Ratio vs. Transmission Range in case of OLSR, FOLSR and FGOLSR in 100m x 100m for 50 Nodes

Experiment was conducted to find the packet delivery ratio against the transmission range by varying the transmission range from 25 m to 50 m for 30 nodes and 50 nodes are shown in the figure 8 and figure 9. In almost all the cases, the proposed FGOLSR method found the maximum number of packets delivered compared to OLSR and FOLSR.

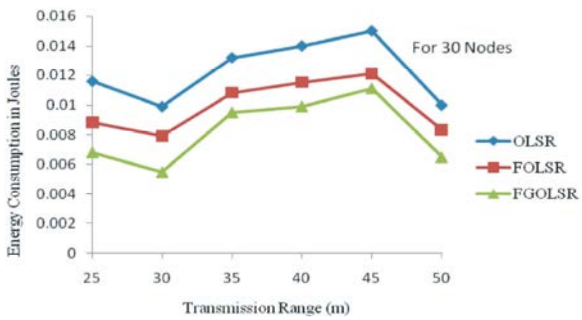

Fig. 10: Energy Consumption vs. Transmission Range in case of OLSR, FOLSR and FGOLSR in 100m x 100m by 30 Nodes

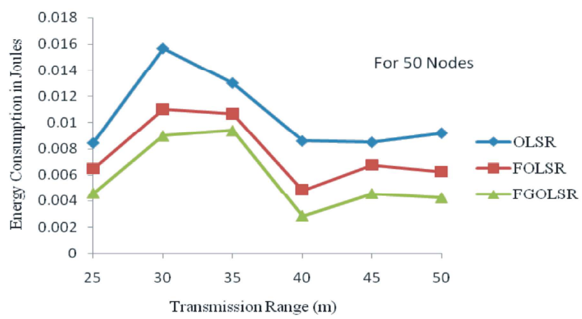

Fig. 11: Energy Consumption vs. Transmission Range in case of OLSR, FQOLSR and FGQOLSR in 100m x 100m for 50 Nodes

Experiment was conducted to find the energy consumption the network against the transmission range by varying from 25 m to 50 m for 30 and 50 nodes are shown in Figure 10 and Figure 11. In almost all the cases, the proposed method found the minimum energy consumption of nodes compared to OLSR and FOLSR because of QMPR.

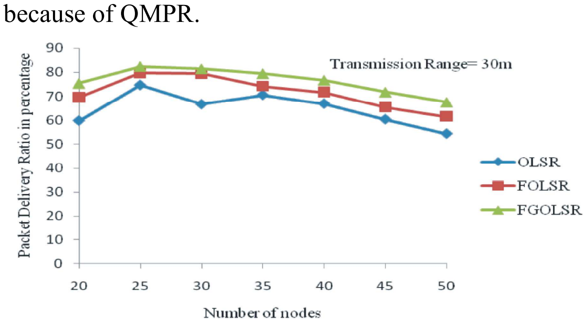

Fig. 12: Packet Delivery Ratio vs Number of Nodes in case of OLSR, FOLSR and FGOLSR in 100m x 100m for Transmission range= 30 m

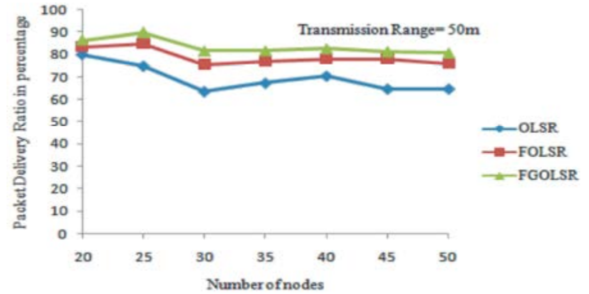

Fig. 13: Packet Delivery Ratio vs Number of Nodes in case of OLSR, FOLSR and FGOLSR in 100m x 100m for Transmission range=50 m

Experiment was conducted to find the packet delivery ratio against the number of nodes by varying from 20 to 50, by fixing the transmission range to 30 m shows in Fig 12 and 50 m shows in Fig 13, in the grid size of 100m x 100m. In almost all the cases, the proposed method found the maximum number of packets delivered compared to OLSR and FOLSR.

Experiment was conducted to find the energy consumption of the network against the number of nodes varying from 20 to 50, by fixing the transmission range to 30m shows in Fig 14 and 50m shows in Fig 15, in the grid size of 100m x 100m. In almost all the cases, the proposed met hod found the minimum energy consumption of nodes compared to OLSR and FGOLSR because of QMPR.

CONCLUSION

There has been lots of research were proposed to select the MPRs for OLSR protocol. The proposed fuzzy logic provides effective guidance in predicting and selecting best nodes as Quality MPR and the genetic algorithm is used to find best path from source to destination for OLSR routing.

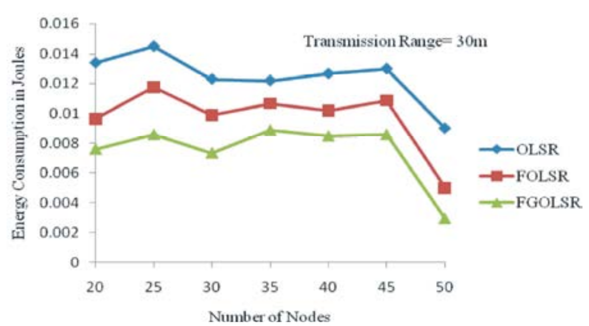

Fig. 14: Energy Consumption vs Number of Nodes in case of OLSR, FQOLSR and FGQOLSR in 100m x 100m for Transmission Range= 30 m

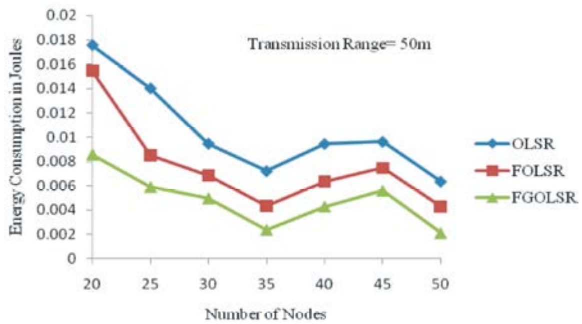

Fig. 15: Energy Consumption vs Number of Nodes in case of OLSR, FOLSR and FGOLSR in 100m x 100m for Transmission Range= 50 m

protocol. From the result it is observed that efficiency of the OLSR routing protocol is improved in terms of packet delivery ratio and the energy consumption. Compared to existing methods, the overall energy consumption of all the nodes is minimized and packet delivery ratio is increased by using the quality MPR selected by the fuzzy logic approach.

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