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Optimal Route Selection Strategy in Wireless Mesh Networks

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***Abstract*— A wireless communication network offers a flexible information transport platform that allows mobile users to roam without suffering intolerable performance degradation networking. Due to the complex infrastructure and mobility of nodes that led to dynamic network topology, therefore, the routing is one of the most important challenges in wireless mesh networks. To overcome these challenges, a number of routing techniques have been developed. This paper focuses on finding the optimal path which using to transfer data. Here, a fuzzy based model (using three input parameters and one output parameter optimal route) is proposed in order to mimic the route discovery mechanism in routing protocols with using new parameters like (Number of hops, Local Battery level, Received Signal Strength Indicator) as the input to fuzzy inference system. A number of fuzzy rules are generated which are very important in reasoning processes for making a final decision about what is path most select.

Keywords— WMN, FIS, AODV, DSR, Optimal route

I. INTRODUCTION

Wireless mesh networks are self-healing, self -configurable, less installation cost and more popular as comparative to other wireless technologies. Wireless networking is allowing businesses to develop WANs, MANs, and LANs without a cable plant. The IEEE has developed 802.11 as a standard for wireless LANs. The impact of wireless communications has been and will continue to be profound. Very few inventions have been able to "shrink" the world in such a manner. A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Wireless networks often consist of mesh clients and mesh routers. Mesh routers contain additional routing functionality due to the presence of wireless interface card in them. Wireless mesh networks are most popular wireless networks due to its support for ad-hoc networking, and capability of self-forming, self-healing and self -organization. Routing in such a wireless network environment is a big challenge due to its design and configuration issues. The design and implementation of routing schemes that are able to effectively and efficiently support information exchange and processing in WMNs is a complex task. Developers must consider a number of theoretical issues and practical limitations such as energy and computation restrictions. A number of research works has been taken out on routing in wireless mesh networks. Mostly the protocols used in wireless ad-hoc networks such as DSR and AODV) are also used in WMN. But no one is compatible to full fill up the desired requirements for WMNs. A number of limitations have been found out by using AODV and DSR for WMN. Such as a limited number of parameters are considered for routing decisions in these protocols. Hence, here a new fuzzy based mechanism for optimal route selection purposes has been proposed. We propose the use of fuzzy logic in the decision-making processes of the DSR routing protocol, in order to select the best nodes to be part of the routes. In this paper, fuzzy logic improves the selection of routing metrics. It details parameter selection and definition, and fuzzy-rule set design. Finally, we show a complete series of simulation results with the help of fuzzy logic toolkit of MATLab 7.0[1].

This paper is structured as follow, in section I a brief introduction about the technology has been explained. Section II discusses the detailed survey about this research while section III tells us about proposed Fuzzy based Mechanism and about the simulation results and discussions about all over the process. At the end of the paper, Section IV concludes this proposed work.

II. LITERATURE SURVEY

Pankaj Sharma et al. proposed a DSR Routing Decision technique for MANET [2]. This technique is based on fuzzy logic system. For this, a number of routing metrics have been applied such as node density, pause time, node mobility, number of packets transferred etc. For simulation purposes

NS-2 and MAT Lab 7.0 has been used. Here, based on routing metrics, the performance of DSR has been analysed.

Taqwa Odey et al. proposed an enhanced AODV routing protocol for mobile ad hoc networks using fuzzy rule based system. Two input variables i.e. hop count and delay is used for the output [3]. Triangular membership functions were used for input and output variables. For performance evaluation purposes, packet delivery ratio, average end-to-end delay, normalized routing load metrics were used. OMNET^{++} 4.0 simulator was used for simulation work.

S.P. Shiva Prakash, T.N. Nagabhushan, Kirill Krinkin has proposed energy aware power save mode in wireless mesh networks [4]. The proposed EAPSM (energy aware power save mode) comprise of energy consumption calculator, transmission mode identifier, PSM (power save mode) Scheduler. Also an algorithm used to schedule PSM of a node has been presented. T.N. Naabhshan et al have proposed a new routing scheme named "minimum battery draining rate aware OLSR (Optimized Link State Routing) scheme for WMNs (Wireless Mesh Networks). In this proposed research work [4], each node declares its willingness value by calculating its own energy status. Based on two metrics named as 'Residual Energy' and 'Draining Rate', MPR Selector works i.e. select the MPRs (Multipoint Relays). In MPR selection process, some of the modules are: create network, install OLSR routing to each node, install RV battery model to each node, calculate available energy, calculate energy draining rate, MPR/Route selection etc. for simulation purposes, network simulator-2 has been used. Also a comparison work of OLSR algorithm and proposed MDRA-OLSR algorithm has been taken out.

Adeel Akram and Mariam Shafqat have proposed a modified AODV protocol for wireless mesh network [5]. To optimize the battery and frequency, AODV protocol has been modified. To remove the conflicts between channel re-use, an algorithm has been implemented in this work. At the last of this research work, a comparison between AODV and proposed modified AODV has been taken.

III. PROPOSED FUZZY BASED MODEL

Fuzzy logic is a powerful approach that has demonstrated to be effective when combining with other disciplines such as routing approaches for WMNs[6][7][8]/ The potential of fuzzy logic goes beyond traditional control systems and can be used on many research fields, allowing multidisciplinary approaches and performance improvements.

The fuzzy logic model is implemented in MATLab utilizing fuzzy logic toolbox. The basic steps of the model are identified of relevant input/output variables, development of fuzzy profile of these input/output variables defining relationships between inputs and outputs variables. Develop fuzzy profile (of identified variables) is the first step in incorporating human knowledge into engineering systems in a systematic and efficient manner.

Input/output variables gathered are fuzzy in nature and is characterized by membership function. We have considered either triangular or trapezoidal membership function, for each variable. Fuzzy membership functions are generated utilizing the linguistic categories such as Low (L), Medium (M) etc identified by a human expert to express his/her assessment. Figure shows membership function and fuzzy profile of all the selected input/output variables for visualization purpose.

In this work, fuzzy inference system has been applied[9]. Three input variables number of hops, local battery level, and signal strength are applied to find out one output variable optimal route.

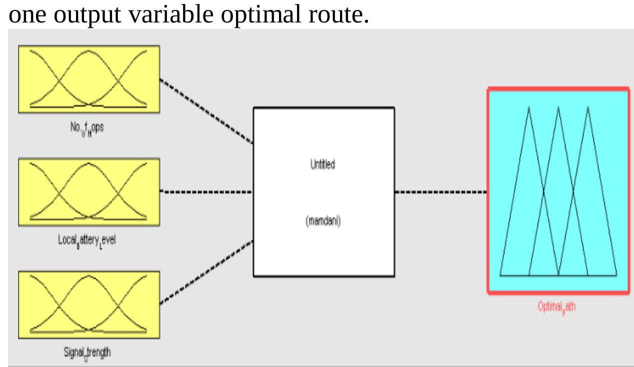

Figure.1: Fuzzy Inference System

Input Variables:

a) No. of Hops----*Low, Medium, High*
b) Local Battery Level---*Low, Medium, High*
c) Signal Strength---*Low, Medium, High*

Triangular type membership function for input variables no. of hops, local battery level, and signal strength has applied in this work.

Output Variable:

Optimal Path---*Low, Medium, High*

Gaussian type membership function has been applied here for output variable 'Optimal Path'.

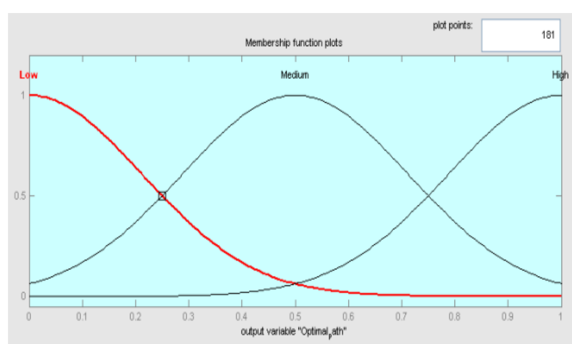

Figure 2: Output variable 'Optimal Path'

Based on three input variables, after applying production rules, an optimal route is found out. Here, twenty seven rules have been generated. Rules are explained as given as below in detail:

Fuzzy Rules:

1. If (No._ of_ Hops is High) and (Local_ Battery_ Level is Low) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
2. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Medium) then (Optimal_ Path is Medium).
3. If (No._ of_ Hops is High) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
4. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Low) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
5. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
6. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Low) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
7. If (No._ of_ Hops is High) and (Local_ Battery_ Level is High) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
8. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is High) and (Signal_ Strength is Medium) then (Optimal_ Path is Medium).
9. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Low) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
10. If (No._ of_ Hops is High) and (Local_ Battery_ Level is High) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
11. If (No._ of_ Hops is High) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
12. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Low) then (Optimal_ Path is Medium).
13. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Low) and (Signal_ Strength is Medium) then (Optimal_ Path is Low).
14. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Low) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
15. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is High) and (Signal_ Strength is Low) then (Optimal_ Path is Low).
16. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Medium) then (Optimal_ Path is Medium).
17. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is High) then (Optimal_ Path is High).
18. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is High) and (Signal_ Strength is Low) then (Optimal_ Path is Medium).
19. If (No._ of_ Hops is High) and (Local_ Battery_ Level is High) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
20. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Low) and (Signal_ Strength is Medium) then (Optimal_ Path is Low).
21. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is High) and (Signal_ Strength is High) then (Optimal_ Path is High).
22. If (No._ of_ Hops is High) and (Local_ Battery_ Level is High) and (Signal_ Strength is Medium) then (Optimal_ Path is Medium).
23. If (No._ of_ Hops is High) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is Medium) then (Optimal_ Path is Low).
24. If (No._ of_ Hops is Medium) and (Local_ Battery_ Level is Medium) and (Signal_ Strength is High) then (Optimal_ Path is Medium).
25. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is High) and (Signal_ Strength is Medium) then (Optimal_ Path is High).
26. If (No._ of_ Hops is High) and (Local_ Battery_ Level is Low) and (Signal_ Strength is Medium) then (Optimal_ Path is Low).
27. If (No._ of_ Hops is Low) and (Local_ Battery_ Level is High) and (Signal_ Strength is High) then (Optimal_ Path is High).

For simulation purposes, here Fuzzy logic toolkit of MATLab7.0 is applied. Based on three input variables (number of hops, local battery level, signal strength and one output variable optimal path), rule viewer and 3D surface viewer results are depicted in fig. 3, fig. 4, fig. 5, fig 6, fig.7 and in fig. 8.

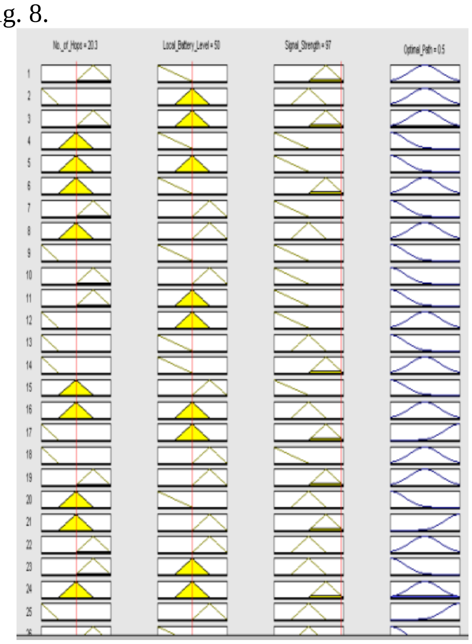

Figure 3: Rule Viewer

A rule viewer has been shown as depicted in fig 3, with no. of hops=20.3, local battery level=50, signal strength=97, and output optimal path=0.5 (medium).

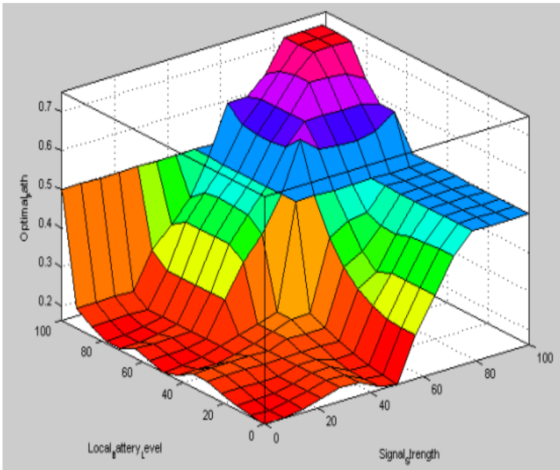

Figure 4: output optimal path w.r.t. local battery level and signal strength

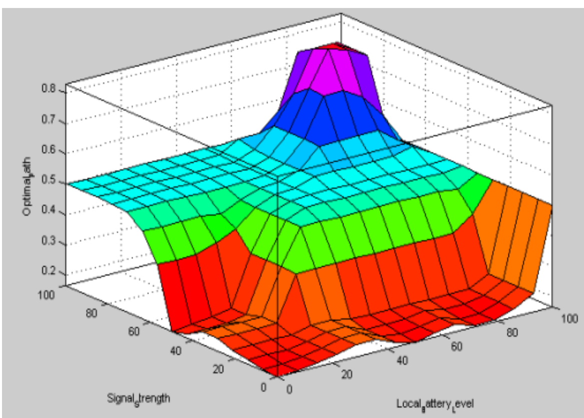

Figure 5: output w.r.t. input variable signal strength and local battery level

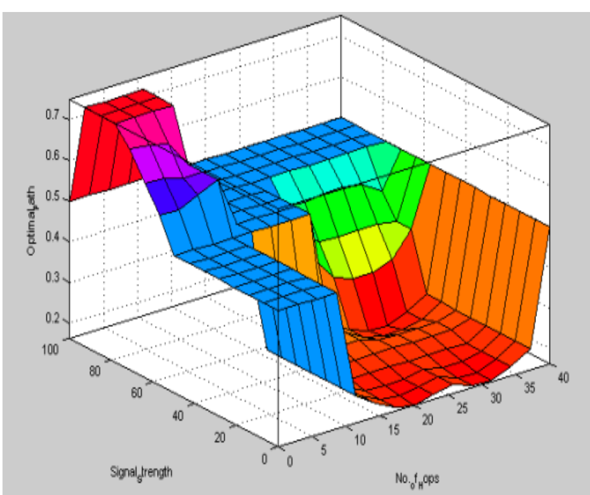

Figure.6: output w.r.t. signal strength and no. of hops

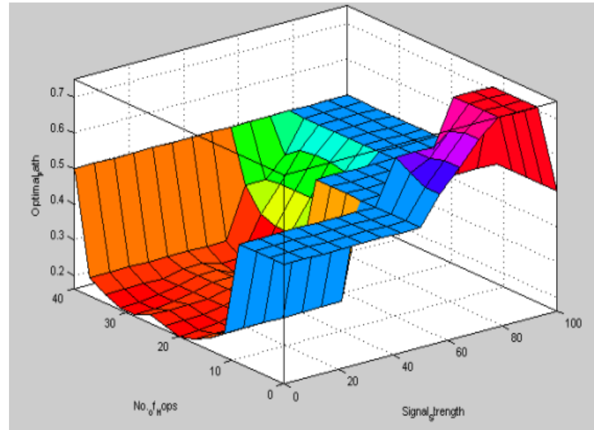

Figure 7: output variable w.r.t. no. of hops and signal strength

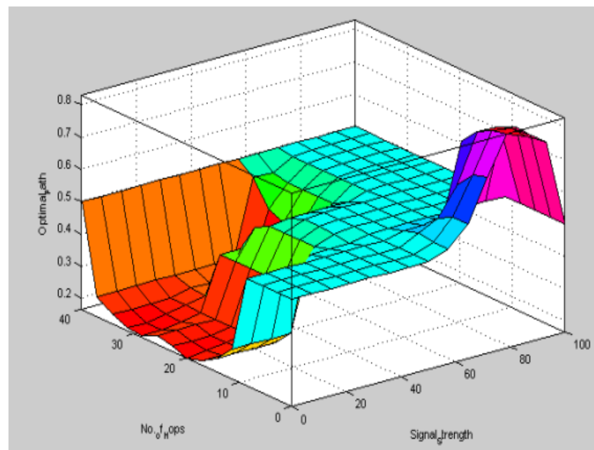

Figure 8: output variable ‘optimal path’ w.r.t. no. of hops and signal strength

A number of test cases have been conducted. Some of the test cases with input variables w.r.t their outputs are explained in detailed as given below:

Table 1: Test cases

Test Case No.	No. of Hops	Low Battery Level	Signal Strength	Optimal Path
Test Case No.1	20	20	50	0.5
Test Case No.2	.927	50	50	.5
Test Case No.3	5.17	50	50	.5
Test Case No.4	9.14	50	50	.5
Test Case No.5	14.4	50	50	.5
Test Case No.6	19.7	50	50	.5
Test Case No.7	20.3	50	50	.5
Test Case No.8	22.29	50	50	.5
Test Case No.9	25.8	50	50	.42
Test Case No.10	29	50	50	.289
Test Case No.11	32.7	50	50	.18
Test Case No.12	35.9	50	50	.21
Test Case No.13	38.3	50	50	.25
Test Case No.14	20.3	2.32	50	.167
Test Case No 15	20.3	10.9	50	.176
Test Case No16	20.3	20.9	50	.192
Test Case No17	20.3	38.1	50	.483

Test Case No18	20.3	55.3	50	.5
Test Case No19	20.3	66.6	50	.5
Test Case No20	20.3	79.1	50	.5
Test Case No21	20.3	83.1	50	0.5
Test Case No22	20.3	97	50	.5
Test Case No23	20.3	50	4.3	.169
Test Case No24	20.3	50	15.3	.183
Test Case No25	20.3	50	25.5	.223
Test Case No26	20.3	50	32.8	.448
Test Case No27	20.3	50	37.4	.48
Test Case No28	20.3	50	50.7	.5
Test Case No29	20.3	50	66.6	.5
Test Case No30	20.3	50	77.2	.5
Test Case No31	20.3	50	88.1	.5
Test Case No32	20.3	50	97	.5
Test Case No33	20.3	95	97	.661
Test Case No34	1.98	95	97	.734
Test Case No35	7.02	95	97	.734
Test Case No36	12.1	95	97	.734
Test Case No37	20	95	97	.734
Test Case No38	21.8	95	97	.509
Test Case No39	25.3	95	97	.509
Test Case No40	29	95	97	.504
Test Case No41	31.4	95	97	0.5
Test Case No42	35.8	95	97	0.5
Test Case No43	39.1	95	97	0.5

These test cases have been summarized in following key points as given below:

- ✓ At medium value of LBL (Low Battery Level) and SS(Signal Strength), when increasing the value of No. of hops then as a result the optimal path value remains at medium level, but when no. of hops are go to the higher position, then as a result the optimal path value go to down position.
- ✓ At the medium level of no. of hops, signal strength, when local battery level value go to high the optimal path value also increased. But the highest value of battery level value, the optimal path value remains constant i.e. at medium level.
- ✓ At constant level of no. of hops, and local battery level (both at medium level) when increasing the signal strength, the optimal path value also go to high. But remains at medium level at the higher and highest value of signal strength.
- ✓ At higher and highest values of the local battery level and signal strength, when no. of hops are increasing, the value of optimal path also increased, but remains at medium level, at the higher and highest values of the no. of hops.

IV. CONCLUSIONS AND FUTURE WORK

Wireless communication is one of the emerging technologies which allow users to access information and services electronically, despite their geographically position.

- Using the fuzzy logic as a metric in network routing improves the performance of real networks.
- Using the fuzzy logic as a metric in network routing improves the performance of the intelligent dense monitoring of the network, thus, led to increasing quality of service.
- The fuzzy logic is a useful and powerful approach that has demonstrated to be effective when combined with other disciplines such as routing approaches for wireless mesh networks (WMNs).
- The routing is one of the most important challenges in ad-hoc networks due to absence of central administration and mobility of nodes; therefore, many techniques ware development to deal with it like fuzzy logic.
- The lack of an efficient metric to evaluate node conditions in routing protocols, has been solved by the definition of a new efficient metric based on the combination of different node and new network parameters by using a Genetic Fuzzy Petri Net system.
- The Fuzzy Inference system is used to select the optimal path, depending on three fuzzy input parameters (number of hops, Local Battery level, Received Signal Strength Indicator) and a set of fuzzy rules. This model is used in order to mimic the route discovery mechanism in wireless mesh network routing protocols to select the optimal path.

Future research work can be done by the addition of new parameters as input to the fuzzy inference system and studying the performance achieved by these new parameters, such as the bandwidth, the load of the link, the traffic load, the power consumption, the total vector cost, the time to life for the path and the node density.

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