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Network Connectivity Analysis of VANET using Fuzzy Logic Controller

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Abstract

To achieve efficient and fast communication network, it is very necessary to resolve the problem of distorted network connectivity and acquire ideal QoS. This research paper focuses on the development of easier approach towards level of node connectivity using fuzzy logic for betterment of the vehicular ad hoc network performance, and, also evaluates an ideal transmission range which would ensure perfect node connectivity for a given number of nodes. Hence, ideal transmission range easily evaluates the network node connectivity for given nodes and compares the simulated results with the connectivity. Network simulations are performed using QualNet 6.1.

Keywords: Mobile Ad Hoc Network, Vehicular Ad Hoc Network, Network Connectivity, AODV Routing Protocol, MATLAB, Fuzzy Logic, QualNet 6.1

INTRODUCTION

A mobile ad-hoc network (MANET) is defined as a wireless network which consists of number of mobile nodes in an infrastructure-less environment. A wireless ad hoc network does not have fixed topology, and its connectivity among nodes is totally dependent on the behavior of the devices, their mobility patterns, distance with each other, etc.Infrastructure-less networks lack any central controller for the nodes, therefore the nodes of such networks possess highly dynamic nature and interconnections of nodes vary continuously. Thus, such wireless ad-hoc networks communicate with the help of routing protocols, which provide routing paths between nodes. In routing process, each node transmits data to other nodes such that the routes are discovered dynamically on a continuous basis, with the help of routing protocols. The main function of any routing protocol is to establish routing path between nodes, which provide efficient transmission of data with minimum delay, expense and bandwidth consumption [1].

Vehicular ad hoc networks (VANETs) are wireless networks developed using the phenomena of mobile ad hoc networks (MANETs) whose spur-of-the-moment formation ensures data trans-reception between vehicles. VANETs ensure road navigation, safety, etc., in vehicle-vehicle and vehicle-roadside networks. Intelligent Transportation Systems (ITS) is based on VANETs, also known as Intelligent Transportation Networks. VANET is the wireless communication network, working through wireless links placed upon each vehicle. VANET nodes also represent as network router via which the nodes communicate with each other. Self Organization occurs in VANET, as it does not depend upon fixed infrastructure. Although some preset nodes perform as the roadside units to aid the vehicular networks for allocating geographical data or access to internet etc. High node mobility, speed and rapid pattern movement are the features of VANET. But, this also results in highly dynamic network topology. In VANET, vehicles follow structured roads, due to which its speed is based on the speed signs and traffic signals [2][3].

QoS (Quality of Service) is defined as the set of parameters, which needs to be fulfilled by mobile ad-hoc networks (MANET) in order to ensure efficient and faster communication between the source and destination nodes. These parameters vary according to the different networking layer. Most commonly used QoS parameters for performance analysis of ad-hoc networks are bandwidth, delay and jitter. Improving QoS parameters for mobile ad-hoc networks is very crucial due to the dynamic nature of MANET topology and decentralization [4].

In this research paper, AODV routing protocol is employed by mobile ad-hoc networks for comparative analysis of QoS parameters between conventional and fuzzy logic based method of obtaining sure network connectivity on the basis of transmission power and number of nodes in a given network [5][6]. Ad-hoc On Demand Distance Vector (AODV) routing protocol is a reactive routing protocol which establish routes on-demand. Thus, the transmission of topology information by nodes occurs only on demand. AODV uses routing tables with one entry per destination. Every node maintains two route entries i.e. (a) broadcast_id which increases each time the source broadcasts a route request packet (b) sequence number to prevent routing loops and to eliminate old, broken routes. Routes are maintained in AODV using RREQ (route request), RREP (route reply) and RRER (route error) control messages [7].

NETWORK CONNECTIVITY

In VANETs, connectivity differs due to the continuous node movement because of their dynamic property, causing network partition. Connectivity Management is difficult due to dynamic network topology, frequent link occurrence and nodes failure via interference, radio channel effects, and mobility and battery limitation. Hence, Connectivity is a major issue in vehicular ad hoc network. The reasons behind failure in the network that divides the network into two or more parts and can obliterate end-to-end connectivity are classified into the following as given below:

A. Node Failure

This happens when an intermediate node working as router is unavailable because of hardware and software failure, and, secondly, when the node is not in communication range of the network. It is also known as Device Failure.

B. Critical Point

In a topology such points are nodes and links which fail and cause network division into two or more parts. It is also known as Weak Point.

C. Link Failure

Link failure happens because of many factors such as link obstacle among communicating nodes, node mobility, fading and high interference. It is also known as Edge Failure.

D. Power Failure

Power failure happens when the node battery is very low, and hence the node cannot work as router. It is also known as Battery Failure [8].

Node connectivity was first defined by Cheng and Robertazziin in 1989. They studied the effect of node density and node's broadcast transmission range in a multi hop radio network followed by spatial Poisson method. They prescribed that for transmission range optimization, its value must be low bounded to achieve ideal network connectivity. But, this method is difficult to implement practically [9]. Based on previous work, this research paper studies the Poisson distributed nodes disconnection. It gives comparison between node's critical coverage range and critical transmission range in a square area based on Poisson fixed density [10]. This issue is studied for one dimensional segment which provides critical range of transmission for Poisson distributed nodes in given area of square. But, these researches were difficult to implement in real situation, since, in Poisson process deployed nodes are originally random variable and only its average value can be determined [11].

Connectivity is the route directness between nodes in a network topology. For a given network with |N| nodes, where N = {n1, n2, n3….n\N\}, and the degree of node (n_j) is deg(n_i), then connectivity is defined as:

$$\text{Connectivity (NW)} = \sum_{i=1}^{|N|} \frac{\deg(n_i)}{\binom{|N|}{2}} \qquad (1)$$

$$\text{Where, } \binom{|N|}{2} = |N|^2\text{-}|N|$$

A Network has full connectivity when the Connectivity of the Network Connectivity (NW) is 1. The necessary condition for full connectivity is described as:

$$\sum_{i=1}^{|N|} \deg(n_i) = |N|^2 - |N| \qquad (2)$$

Full connectivity implies that the transmission range of a network is more than or equal to the longest distance between any given node pair in the network and the node degree is |N|−1. The nodes in this network are capable of transferring data. But, the required transmission range is higher. This network topology results into high channel interference, which lowers the network QoS due to very high transmission range.

Each node has a definite maximum transmission power rangeP_{MAX}. $P_a$is the transmission power of node a. α is the path loss exponent and τ is the minimum average SNR required for decoding received data. d_{ab} is the distance between node a and node b. For a source node i to communicate with node j in a given straight line as shown in Figure 1, it should follow [12]

$$P_a(d_{ab}) - \alpha \geq \tau \qquad (3)$$

Where, $P_a \leq P_{MAX}$

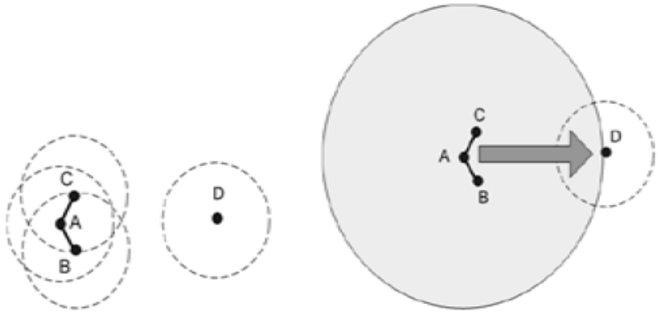

Figure 1. Effect of Transmission Range on Network Connectivity

FUZZY LOGIC

In this research paper, MATLAB software is utilized to embed the concept of fuzzy logic, in order to provide an easier and feasible approach towards perfect network connectivity for a given transmission range and number of nodes in a wireless ad hoc network, thereby, ensuring efficient network performance by improving QoS. In MATLAB's Fuzzy Logic Toolbox, FIS editor is provided for fuzzy inference system development. Mamdani's fuzzy inference system is taken in this research paper. The block description of mamdani's fuzzy inference system is given in Figure 2 [13][14].

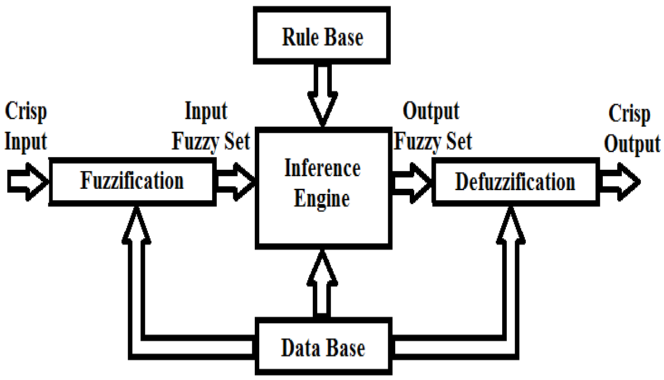

Figure 2. Block Description of Fuzzy Inference System

The crisp inputs are transformed generating input fuzzy set through fuzzification. After that, the inference engine computes the output fuzzy set with the help of knowledge base which comprises of fuzzy if-then rules in rule base and knowledge about linguistic functions to map called membership functions of the I/O fuzzy set in data base. Finally, the output fuzzy set is transformed generating crisp outputs. Fuzzy Logic is analogous to the human brain functioning, thus enabling feasible computational learning, making it suitable for incorporation to ensure higher network connectivity by establishing simpler rules between number of nodes and transmission range in a wireless ad hoc network [14].

PROPOSED WORK

The implemented fuzzy inference system is given in Figure 3. It consists of two inputs, i.e., number of nodes having membership functions {Low, Medium, High} and transmission range having membership functions {Low, Medium, High} and one output, i.e., network connectivity having membership functions {Moderately-Connected, Surely-Connected}. The Input-Output variables associated with FIS are given in Figure 4, Figure 5 and Figure 6, retrieved from MATLAB fuzzy logic toolbox.

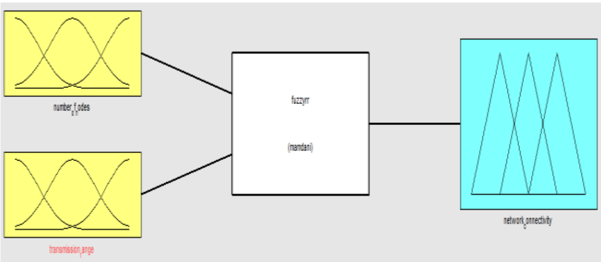

Figure 3. Fuzzy Inference System

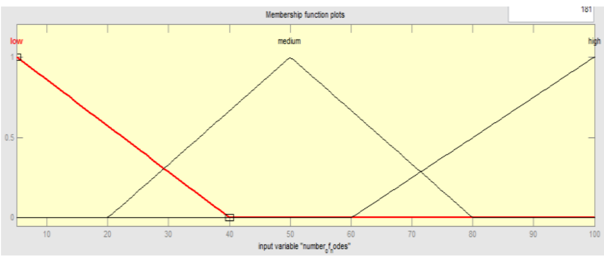

Figure 4. Number of Nodes

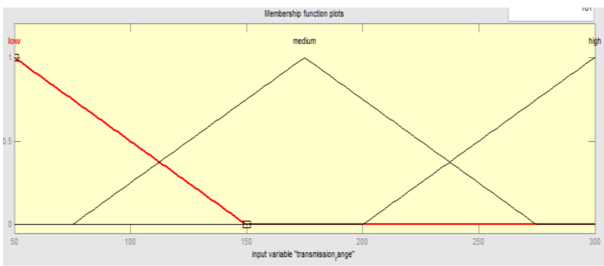

Figure 5. Transmission Range

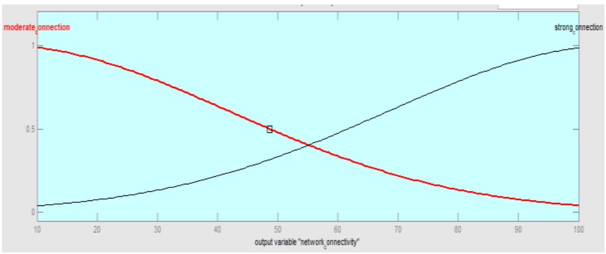

Figure 6. Network Connectivity

The fuzzy rules are described, which are created in the rule editor, for the implemented fuzzy inference system in Table 1, given below [5]:-

Table I. Fuzzy Rule Base

Number of Nodes / Transmission Range	Low	Medium	High
Low	Moderate Connection	Moderate Connection	Moderate Connection
Medium	Strong Connection	Strong Connection	Strong Connection
High	Strong Connection	Strong Connection	Strong Connection

The output consequent to given set of inputs can be obtained using rule viewer, which is graphically depicted using surface viewer. Figure 7 represents the snapshot of FIS rule viewer and Figure 8 represents the FIS surface viewer, given below:-

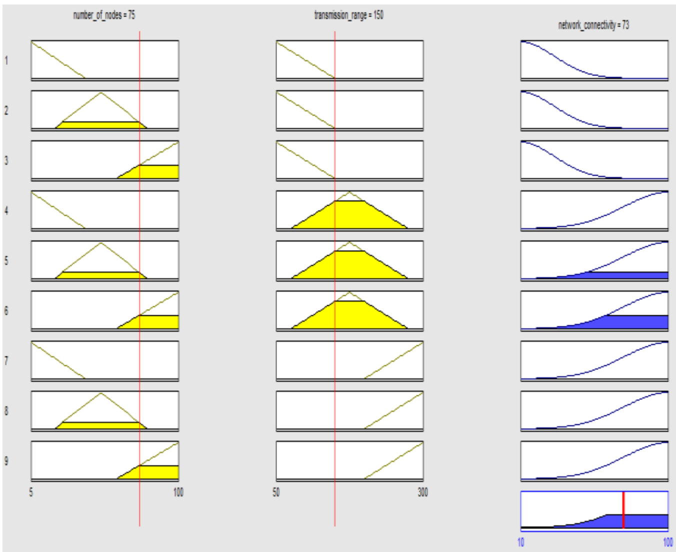

Figure 7. Snapshot of FIS Rule Viewer

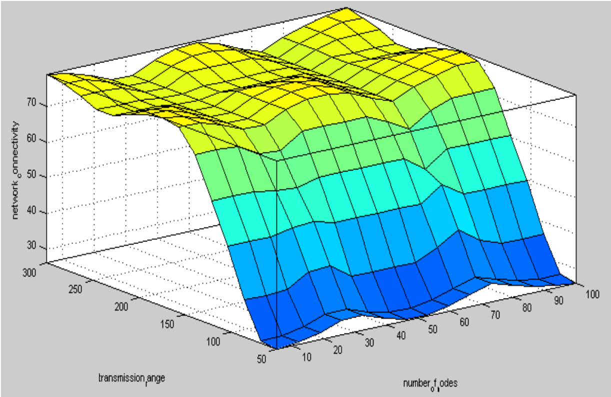

Figure 8. FIS Surface Viewer

In Fuzzy Simulation, estimation of network connectivity is being done on the basis of number of nodes and transmission range, which are given in Table 2, as shown below:

Table II. Fuzzy Based Node Connectivity

Transmission Range, m / Number of Nodes	100	150	250
25	49.2	73.8	73.8
50	47.5	77.4	74.8
75	50.6	73	73
100	47.5	77.4	74.8

SIMULATION ENVIRONMENT AND PARAMETERS

In this research paper, QualNet 6.1 network simulator is utilized to carry out the network simulations. QualNet 6.1 network simulator is an effective medium to examine the performance of any real world communication/data network through simulation process and make enhancements by employing suitable variations in simulation parameters. It is also widely exploited to develop effectual real time communication/data networks, in terms of its performance [15].

The simulation parameters are described below as shown in Table 3:

Table III. Simulation Parameters

Parameters	Value
Simulation Area	1000 x 1000m2
Simulation Time	300 seconds
Number of Nodes	25,50,75,100
Routing Protocol	AODV
CBR	5,10,15,20
Packet Size	512 bytes
MAC Layer	IEEE 802.11
Traffic Type	Constant Bit Rate (CBR)
Transmission Range	100,150,250 m
Antenna Model	Omni Directional

Some of the snapshots of the simulation process, for different transmission range, employed for different number of nodes for analysis of improved node connectivity of the network, are shown below, retrieved from QualNet network simulator:

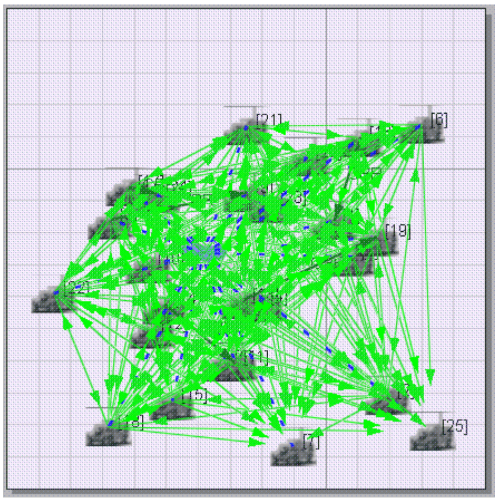

Figure 9. Snapshot of 25 nodes during Simulation employing 100 m Transmit Range

RESULTS AND ANALYSIS

The performance parameters regarding measure of network connectivity are computed for various numbers of nodes ranging from 25 to 100 nodes using varying transmission range, namely 100,150,250 m. These performance parameters include generated packet, received packet, forwarded packet, packet delivery ratio, total packets dropped and average end-to-end delay. The respective performance parameter tables for various nodes are shown below:-

Table IV. Performance Parameters for 25 nodes

Transmission Range / Network Parameters	100	150	250
Generated Packet	120	145	150
Received Packet	40	109	105
Forwarded Packet	10	48	90
Packet Delivery Ratio	0.5	0.93	0.95
Total Packets Dropped	7	21	73
Average End to End Delay (ms)	15.55	125.9	65.49

Table V. Performance Parameters for 50 nodes

Transmission Range / Network Parameters	100	150	250
Generated Packet	151	243	271
Received Packet	100	153	233
Forwarded Packet	52	117	145
Packet Delivery Ratio	0.5	0.96	0.95
Total Packets Dropped	14	45	84
Average End to End Delay (ms)	32.167	938.592	258.61

Table VI. Performance Parameters for 75 nodes

Transmission Range	**100**	**150**	**250**
Network Parameters			
Generated Packet	224	310	356
Received Packet	155	167	225
Forwarded Packet	87	115	155
Packet Delivery Ratio	0.2	0.78	0.92
Total Packets Dropped	20	51	111
Average End to End Delay (ms)	33.593	742.563	229.135

Table VII. Performance Parameters for 100 nodes

Transmission Range	**100**	**150**	**250**
Network Parameters			
Generated Packet	256	353	419
Received Packet	154	175	266
Forwarded Packet	122	130	157
Packet Delivery Ratio	0.2	0.85	0.95
Total Packets Dropped	53	65	126
Average End to End Delay (ms)	51.871	957.043	371.44

From above performance parameters tables, it can be concluded that in case of 150 m, there are fewer packets generated and average end to end delay increases while packet delivery ratio drops, as compared to that of 250 m, in all the cases of nodes , namely from 25 to 100 nodes. For transmission range 100 m, although packets are generated in all cases, the number of nodes forwarded to the destination is very less. Hence, 250 m transmission range is best suited for sure connectivity in given networks containing defined number of nodes.

CONCLUSION

With the help of this research paper, performance of vehicular ad-hoc networks can be enhanced using network connectivity improvement, through transmission range and number of nodes in a fuzzy based approach, thereby, improving QoS. Node Connectivity has been analyzed using fuzzy logic as well as QualNet, which concludes that better QoS is achieved in given networks of defined number of nodes through 250 m transmission range.

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