ISSN: 2229-6948(ONLINE)
DOI: 10.21917/ijct.2016.0210

FUZZY BASED ROBUST AND DELAY AWARE ROUTING IN WIRELESS MESH NETWORK

A. Mercy Rani[1] and V. Lakshmi Praba[2]
[1]*Department of Computer Science, Manonmaniam Sundaranar University, India*
E-mail: mercydurai39@gmail.com
[2]*Department of Computer Science, Rani Anna Government College for Women, India*
E-mail: vlakshmipraba@rediffmail.com

Abstract
The reliability of the network is significant for achieving effective communication in the network. The Quality of Service factors node's energy and queue size play vital role for establishing efficient routing in the network. These factors offer reliability in the network through robust and rapid transmission of data. Hence, in this paper these two factors are mainly considered for choosing the best forwarding neighbors during the transmission. Routing with more than one constraint is a NP-Complete problem and it does not have a polynomial solution. Thus, the efficient route construction based on multiple constraints can be achieved through any optimization technique. Fuzzy Logic is one of the optimization techniques for finding an optimum solution for multi constraint problem. The proposed work enhances the existing AODV protocol as Fuzzy-AODV by implementing Fuzzy Logic technique for choosing the best forwarding neighbors based on node's energy and queue size. The simulation analysis is performed using NS-2. The performance of the network is analyzed by considering the metrics such as packet delivery ratio, packet loss, end-to-end delay, throughput and routing overhead.

Keywords:
Fuzzy Logic, Energy, Queue Size, Optimization, Throughput, Fuzzy-AODV

1. INTRODUCTION

Wireless Mesh Network is a promising technology to offer Broadband Internet access with wide area coverage, high bandwidth network connectivity at lower cost. It provides high reliability and high speed internet access to the users in the network. With the help of WMN, people who live in rural areas can connect their networks in affordable mode [1]. The architecture of WMN includes Mesh Routers (MR), Mesh Clients (MC) and Gateway (G). The Mesh Routers act as mesh backbone infrastructure for providing connections between mesh clients. The mesh clients are mobile devices such as Laptop, PDA, mobile etc. The architecture of WMN is shown in Fig.1. The applications of WMN such as Disaster recovery, High speed last mile Internet access, Video Conferencing and low-cost backhaul services for large area coverage require Quality of Service (QoS) [2] [3] routing for supporting effective communication in the network. The efficient route construction process plays an important role in WMN for offering the above to the end-users of the network. One way of constructing an efficient route from the source to the destination is by choosing the best neighbors for forwarding the packets in the transmission.

The reactive and proactive routing protocols [4] assist the users for finding the route between source and destination. The route in the network can be established by the factors such as hop count, energy, link quality, bandwidth, transmission rate and queue length etc. Many of the ad-hoc routing protocols decide the route based on hop count. However, the hop count route may go ahead with disconnection of the route due to loss of energy. It may also increase the transmission time irrespective of its queue size. The proposed work mainly considers node's energy and queue size constraints for selecting the forwarding neighbor in the network. Routing with more than one constraint is a NP-Complete [5] problem and it does not have a polynomial solution. Fuzzy Logic [6] is one of the suitable approach for choosing best neighbor with the consideration of more than factor in the transmission.

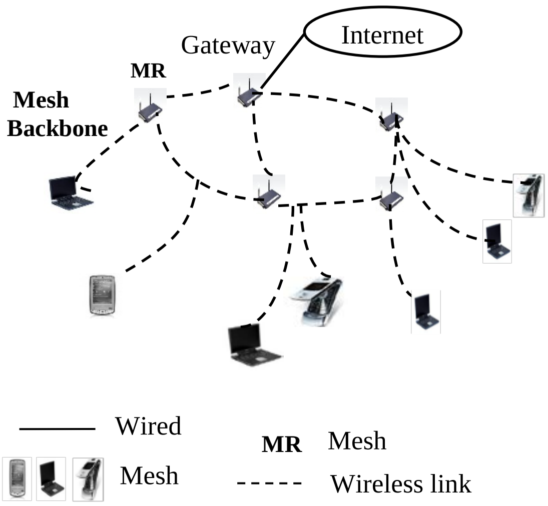

Fig.1. Architecture of Wireless Mesh Network

The rest of the paper is arranged as follows: Section 2, presents the related work. Section 3 describes the quality of service factors used in the proposed work. Section 4 explains the enhanced Fuzzy-AODV based routing in WMN and its simulation performance results are discussed in section 5. Finally, section 6 concludes the paper.

2. RELATED WORK

In Sharma et al. [7] the fuzzy logic based hybrid performance metric is designed. It comprises the parameters such as per flow throughput, delay and jitter along with node's residual energy. The Integrated Link Cost (ILC) is computed by the fuzzy logic based hybrid performance metric. The ILC measures the distance between two adjacent nodes. It also proposed three natures stimulated computing methods such as firefly algorithm, Ant Colony Optimization and Big Bang Big Crunch. The main aim of these methods is, they find the minimum ILC path within a required time. The time factor is determined by the mobility of nodes in the network. The performance of the proposed methods is analyzed in various WMN topologies. The analysis showed that the self-organizing capability of the proposed nature stimulated routing approaches efficiently decreases the complexity of the network. Maria Zogkou et al. [8] proposed a new energy-aware routing metric for the IEEE 802.11s mesh networks. This routing metric considered the energy consumption of mesh nodes to increase the networks lifetime. The new routing metric prolongs network lifetime than the default routing metric which is used by IEEE 802.11s Standard though it increases the higher total delay in the network. M.N. Doja et al. [9] used the fuzzy interference system for analyzing the performance of reactive routing protocols AODV and DSR. Moreover, these protocols are analyzed further in two cases such as with and without fuzzy inference system. Sethi et al. [10] suggested a new Fuzzy-based Trusted Ant Routing (FTAR) approach using fuzzy logic and swarm intelligence. This approach considered multiple objectives optimization for selecting optimal path between source and destination. The benefit of swarm intelligence algorithm is combined with fuzzy logic to provide trusted routing protocol. The trust evaluation scheme is used to determine the trust value. This scheme uses dropped packets and time-ratio parameters for calculating the trust value which distinguishes between healthy and malicious nodes. This FTAR approach considered the shortest path as well as the neighbours' trusted level for routing. Gomes et al. [11] gave the variation of the Optimized Link State Routing (OLSR) for achieving QoS and QoE requirements in multimedia applications. The Fuzzy Link Cost (FLC) metric is used to determine the best path for routing multimedia packets. The proposed FLC used the fuzzy logic system with two link quality metrics such as Expected Transmission Count (ETX) and Minimum Delay (MD). The performance of the proposed metric FLC is compared against existing OLSR protocol.

Though the researchers used fuzzy logic approach for providing trusted routing protocol, efficient energy utilization, trust value calculation of route etc., the route selection based on energy and queue constraints is not concentrated. Thus, the proposed work enhanced AODV protocol with the aforementioned factors for the selection of best forwarding neighbours during the transmission by implementing Fuzzy Logic approach.

3. QUALITY OF SERVICE (QOS) METRICS

3.1 ENERGY

Node's Energy is a significant factor for reliable transmission of packets from source to destination. The node drains its energy when packets are sent or received [11].

3.2 QUEUE SIZE

Queue is a main factor for reducing the delay and congestion problems. Each node in the network has a queue; it acts as a buffer for storing packets temporarily before they get for transmission. The queue size determines the maximum number of packets that can be stored in the queue which indicates the load of a node [11].

4. FUZZY BASED ROUTING IN WMN

The proposed work enhances the existing AODV protocol as Fuzzy-AODV. During the route construction process, this enhanced protocol selects the forwarding neighbors based on the constraints node's Energy and Queue Size by implementing Fuzzy optimization technique. Thus, the RREQ and RREP packets of AODV protocol are modified by adding the fields Energy and Queue Size. The Energy field is used for finding the node's remaining energy and the Queue Size field is used for determining the number of packets waiting in the queue.

Fuzzy logic is one of the soft computing approaches to provide an optimum solution for any complex problem. The main advantage of fuzzy logic is that the rules are placed in natural language which is easily understandable by the user. The truth values or membership values are identified through a value in the range from 0.0 to 1.0 whereas the lowest value 0.0 represents the absence of the value and the highest value 1.0 represents the absolute presence of the value. The Fuzzy Logic System [12] [13] consists of various components like fuzzification, inference engine, rule base and defuzzification. The components of fuzzy logic system are depicted in Fig.2.

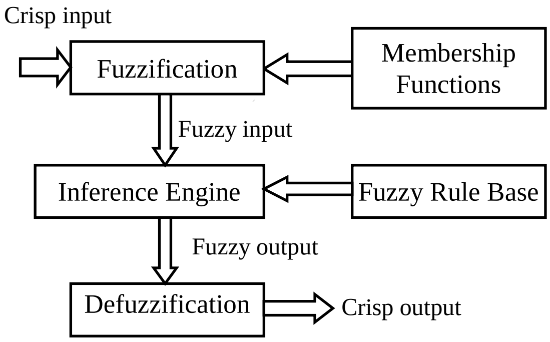

Fig.2. Fuzzy Logic System

4.1 THE ALGORITHM OF FUZZY BASED ROUTING IS AS FOLLOWS

4.1.1 Step 1-Identifying Crisp Input & Membership Functions:

- Current node's Energy and Queue Size are considered as a crisp set of input.
- The membership function is used to map the crisp set with the fuzzy set by using linguistic values. The linguistic values of Energy are Minimum, Medium and Maximum and the linguistic values of Queue Size are Small, Average and Large. The membership values of Energy and Queue Size is described in Table.1 and Table.2. The membership functions of Energy and Queue Size are shown in Fig.3 and Fig.4.

Table.1. Membership values of Energy

Crisp Input	**Energy**		
Crisp Values	0-30	20-80	70-100
Linguistic Values	Minimum	Medium	Maximum
Membership degree	0.0-0.3	0.2-0.8	0.7-1.0

Table.2. Membership values of Queue Size

Crisp Input	Queue Size		
Crisp Values	0-15	11-40	35-50
Linguistic Values	Small	Average	Large
Membership degree	0.0-0.3	0.2-0.8	0.7-1.0

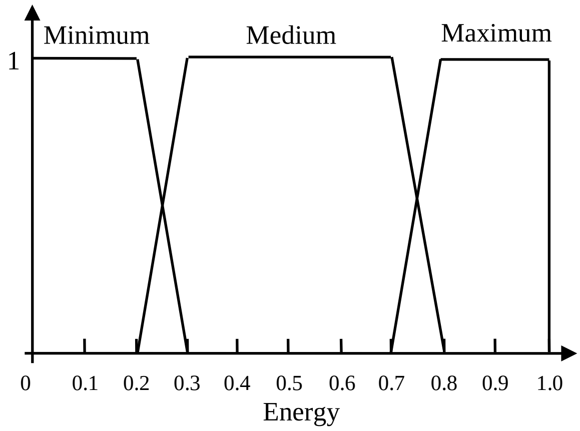

Fig.3. Membership Functions for the fuzzy variable "Energy"

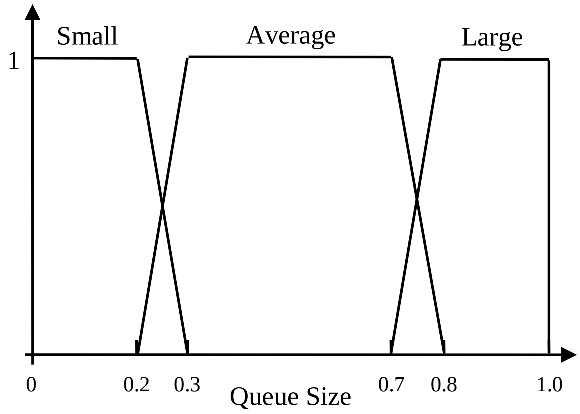

Fig.4. Membership Functions for the fuzzy variable "Queue Size"

4.1.2 Step 2 - Fuzzification:

The crisp inputs are converted into fuzzy set values using the membership functions which are known as fuzzification. This process is carried out by mapping the real world crisp values into the range 0.0 to1.0 through membership function.

4.1.3 Step 3 - Inference Engine:

The inference engine considers the fuzzy inputs and searches through the fuzzy rule base to find out the fuzzy output for each value of the fuzzy sets. The rule base for the values of fuzzy set is given in Table.3.

4.1.4 Step 4 - Defuzzification:

The defuzzification process produces a crisp output such as Optimal, Sub-optimal or Below optimal from fuzzy output which are in the range from 0.0 to 1.0 through the membership functions.

Table.3. Rule Base

Energy	Queue Size	Solution
Minimum	Small	Sub-optimal
Minimum	Average	Sub-optimal
Minimum	Large	Below Optimal
Medium	Small	Sub-optimal
Medium	Average	Sub-optimal
Medium	Large	Sub-optimal
Maximum	Small	Optimal
Maximum	Average	Sub-optimal
Maximum	Large	Sub-optimal

4.2 ROUTING PROCESS OF FUZZY-AODV

During the route discovery process of Fuzzy-AODV, the source broadcasts the RREQ packet to its neighbors. The neighbors receive the packets and determine its routing constraint based on the Fuzzy system. The Fuzzy system groups the neighbors energy values into minimum, medium and maximum and queue size values into small, average and high based on the membership functions. It is converted into fuzzy input and it is entered into Inference Engine. The Inference Engine uses the rule base finds the fuzzy output for that node. The fuzzy output of that node determines whether the neighbor has to forward the RREQ packet or not. The packet forwarding is rejected only when the Energy is Minimum and the Queue size is Large. This process continues until it reaches the destination.

When the RREQ packets reach the destination, it sends the RREP packet to the source through in which the RREQ packet is arrived. The source accepts all the RREP packets and takes the one which has minimum hop count. The further process of Fuzzy-AODV is similar to AODV protocol.

5. SIMULATION PROCESS & RESULTS

The performance of Fuzzy-AODV is analyzed using NS-2 [14]. The network simulation model is constructed with a grid of 7×7 mesh routers and 100 mesh clients. The mesh routers provide backbone infrastructure for establishing connection between mesh clients. Each node has been assigned with an initial energy of 100 Joules and a queue size of 50 packets.

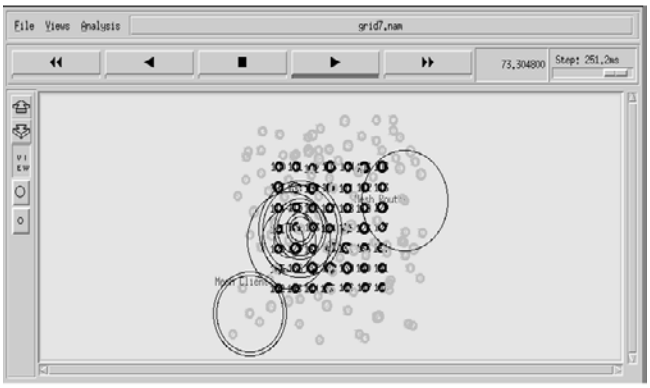

Fig.5. Simulation Layout

The simulation parameters set in the network model is given in Table.4. The analysis of Fuzzy-AODV is conducted by varying the number of traffic flows and it is compared with AODV. The Fig.5 shows the simulation layout of the network model.

Table.4. Simulation Parameters

Parameter	Value
Simulation	NS-2
Simulation area	1200×1200m
MAC	IEEE 802.11
Simulation time	200s
Transmission range	250m
Packet Size	512 bytes
Transmission rate	1Mb
Traffic Type	CBR
No. of Mesh Clients	100
No. of Mesh Routers	49
Routing Protocol	AODV

5.1 PERFORMANCE METRICS

Packet Delivery Ratio (%):

PDR = No. of Packets Received/No. of Packets Sent × 100

Packet Loss:

Packet Loss = No. of Packets Sent – No. of Packets Received

Average End-End Delay (ms):

Avg. End-End Delay = ∑(Total Delay/No. of Delivered Packets) /Number of Nodes

Average Throughput (Kbps):

Avg. Throughput = No. of Delivered Bits/1000

Routing Overhead:

Routing overhead = No. of data packets received/No. of control packets generated

The charts in Fig.6 to Fig.10 show the performance of the proposed Fuzzy-AODV and AODV protocols on the basis of metrics packet delivery ratio, packet loss, average end-to-end delay, average throughput and routing overhead by varying the number of traffic flows.

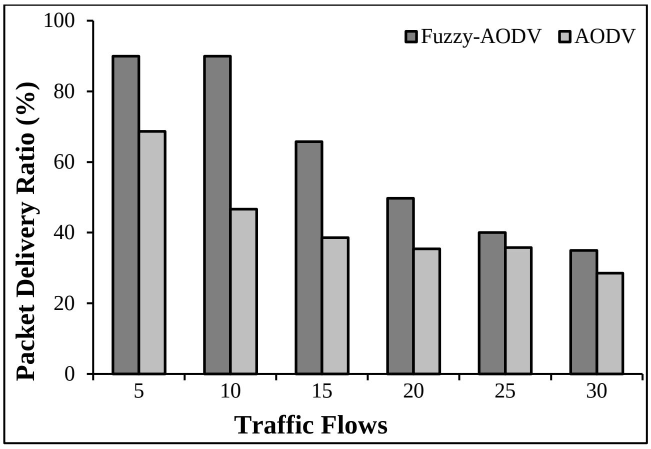

Fig.6. Packet Delivery Ratio vs. Traffic Flows

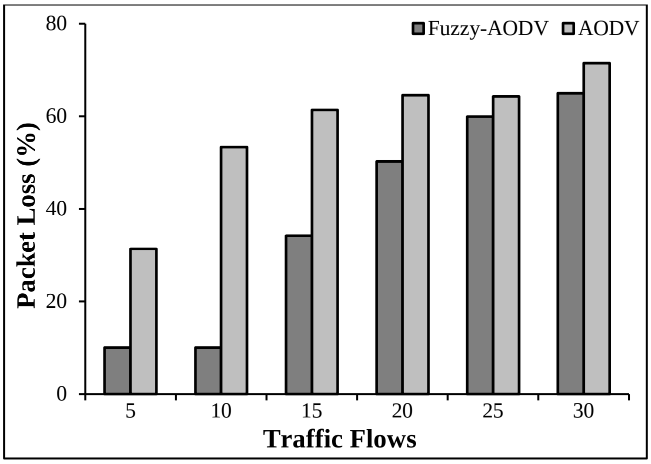

Fig.7. Packet Loss vs. Traffic Flows

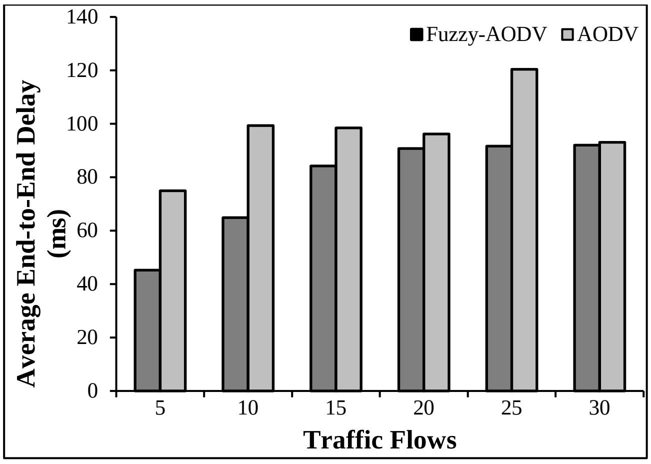

Fig.8. Average End-to-End Delay vs. Traffic Flows

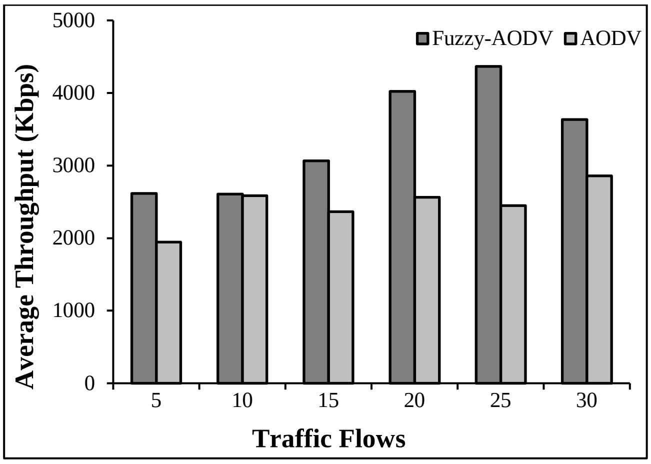

Fig.9. Average Throughput vs. Traffic Flows

The analysis showed that the Fuzzy-AODV provides best results in packet delivery ratio and packet loss than AODV. Due to the consideration of Queue Size the packets reached the destination very quickly. Thus the delay of Fuzzy-AODV is less when compared with AODV. In Fuzzy-AODV, the throughput increases when the traffic flow is very less on the other hand and it decreases when the traffic flow increases. However, the throughput of Fuzzy-AODV is higher than AODV. The routing overhead of Fuzzy-AODV is minimum than AODV except traffic flows 20, it indicates that lesser number of control packets are generated in Fuzzy-AODV than AODV. Thus the above performances reveal that, the Fuzzy-AODV provides best performance than AODV in all the considered traffic flows.

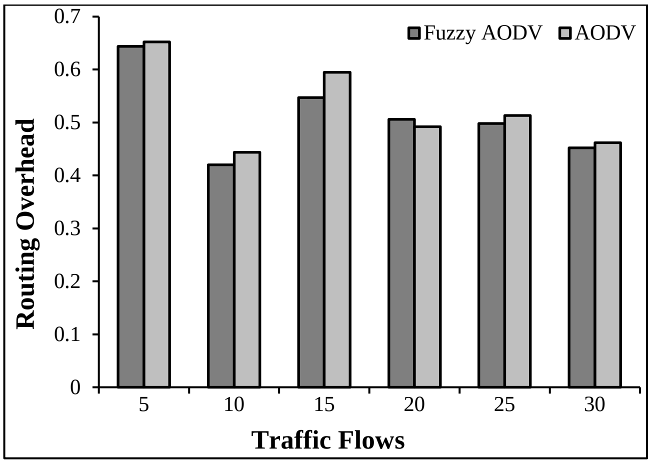

Fig.10. Routing Overhead vs. Traffic Flows

6. CONCLUSION

Routing with more than one constraint is a recent approach in Wireless Mesh Network. In this paper, the existing AODV protocol is enhanced by implementing fuzzy logic with the constraints energy and queue size for selecting the best neighbors in the transmission. The comparative analysis of Fuzzy-AODV and AODV protocols with the consideration of the metrics PDR, packet loss, delay, throughput and routing overhead is discussed in simulation analysis. The analysis showed that the Fuzzy-AODV provides best results in all the considered metrics since Energy constraint provides strong and robust route and the Queue Size gives rapid transmission of data.

REFERENCES

[1] Ian F. Akyildiz, Xudong Wang, and Weilin Wang, "Wireless Mesh Networks: A Survey", *Computer Networks*, Vol. 47, No. 4, pp. 445-487, 2005.

[2] Wireless Mesh Network, Available at: http://en.wikipedia.org/wiki/Wireless_mesh_network

[3] Quality of Service, Available at: http://en.wikipedia.org/wiki/Quality_of_service

[4] List of Ad Hoc Routing Protocols, Available at: http://en.wikipedia.org/wiki/List_of_ad_hoc_routing_protocols.

[5] Turgay Korkmaz and Marwan Krunz, "Multi-Constrained Optimal Path Selection", *Proceedings IEEE 20th Annual Joint Conference of the IEEE Computer and Communications Societies*, pp. 834-843, 2001.

[6] Fuzzy Logic, Available at: https://en.wikipedia.org/wiki/Fuzzy_logic

[7] Sharma, Sharad, Shakti Kumar and Brahmjit Singh. "Routing in Wireless Mesh Networks: Three New Nature Inspired Approaches", *Wireless Personal Communications*, Vol. 83, No. 4, pp. 3157-3179, 2015.

[8] Maria Zogkou, AggelikiSgora and Dimitrios D. Vergados, "Energy Aware Routing in IEEE 802.11s Wireless Mesh Networks", *Proceedings of International Conference on Wireless Information Networks and Systems*, pp. 1-6, 2013.

[9] M.N. Doja, Bashir Alam and Vivek Sharma, "Analysis of Reactive Routing Protocol using Fuzzy Inference System", *Proceedings of International Conference on Parallel and Distributed Computing Systems*, pp. 164-169, 2013.

[10] Srinivas Sethi and Siba K. Udgata, "Fuzzy-based Trusted Ant Routing (FTAR) Protocol in Mobile Ad Hoc Networks", *Proceedings of International Workshop on Multi-disciplinary Trends in Artificial Intelligence*, pp. 112-123, 2011.

[11] Rafael Lopes Gomes et al., "Using Fuzzy Link Cost and Dynamic Choice of Link Quality Metrics to Achieve QoS and QoE in Wireless Mesh Networks", *Journal of Network and Computer Applications*, Vol. 34, No. 2, pp. 506-516, 2011.

[12] Kevin Fall and Kannan Varadhan, "The Ns Manual (formerly Ns Notes and Documentation)", The VINT Project, pp. 1-418, 2010.

[13] Ulrich Hohle and Stephen Ernest Rodabaugh, "*Mathematics of Fuzzy Sets: Logic, Topology, and Measure Theory*", 1st Edition, Springer, 2012.

[14] John Harris, "*An Introduction to Fuzzy Logic Applications*", 1st Edition, Springer, 2000.

[15] NS-2 Network Simulator, Available at: http://www.isi.edu/nsnam/ns.