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Research Article

Routing for Wireless Mesh Networks using Agent based Scheme

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Abstract

Wireless Mesh Networks are self organizing, self configurable, self-healing wireless networks. Due to complex infrastructure of WMN, to maintain the quality of service is a tedious task. In this paper, a QoS routing scheme has been proposed. This scheme is based on two models named fuzzy inference system model and agent based model. Both models are installed on each and every node on the network. In this proposed work, routing is taken place based on AODV, but here mobile agents perform the task of RREQ, RREP packets. By considering parameters number of hops, bandwidth, and packet loss rate at FIS, an output parameter delay is achieved. At the source node, fuzzy static agent decides whether node on a path satisfies delay requirement (for an application) according to the user by considering fuzzy parameters no. of hops, packet loss rate and bandwidth.

Keywords: *AODV, fuzzy rules, mobile agent, static agent, WMN*

1. Introduction

WMN consists of mesh routers and mesh clients. Different from traditional wireless networks, WMN is dynamically self-organized and self-configured. In other words, the nodes in the mesh network automatically establish and maintain network connectivity. Moreover, the gateway and bridge functionalities in mesh routers enable the integration of wireless mesh networks with various existing wireless networks, Wi-Fi (wireless-fidelity), increased reliability, low installation costs, large coverage area, automatic network connectivity are the some benefits and characteristics of wireless mesh networks. There are two types of nodes in WMNs: Wireless Mesh Routers and Mesh Clients. Due to dynamic self-configuration and self-organization, fault tolerance and robustness, low cost, integration and interoperability characteristics, WMNs are popular wireless technology. IEEE 802.11s is the most relevant emerging standards for WMN technology.

The design of the routing protocols for WMNs is still an area of research although there are many routing protocols that are available for ad-hoc networks. Multiple performance metrics, scalability, robustness and efficient routing with mesh infrastructure are some features which must be possessed by an optimal routing protocol for WMN.

The nodes in a WMN automatically detect neighbor nodes and establish and maintain network connectivity in an ad-hoc fashion.

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Some factors influencing performance of WMN : (a) Radio Technique (b) Scalability (c) Security (d) Broadband (e) QoS (f) Ease of Use (g) Compatibility and Inter-Operability.

Mobile agent technology has been promoted as an emerging technology that makes it much easier to design, implement, and maintain distributed systems, including cloud computing. Quality of Service (QoS) support in Wireless Mesh Networks (WMNs) is a challenging task due to bandwidth and delay constraints, varying channel conditions, power limitations, node mobility and dynamic topology. This paper proposes a software agent based QoS routing scheme in WMNs by using software agents that employ neuro-fuzzy logic. The paper is sectioned into five modules. Section 1 explains about the brief introduction and problem description. In section 2, a literature work has been explained shortly. The main proposed work is described in section 3. Section 4 gives the detailed technique of agent based model. At last section 5 conclude the paper.

2. Literature Survey

V.Ponnyin Selyan (2012) *et al*. proposed an optimized AODV protocol for wireless Networks. Here, Ant Mesh Network AODV for MANET is proposed. AODV is modified to include the ant colony based optimization.
M.Nasim Faruque (2001) *et al*. proposed a packet scheduling algorithm for WANET. This algorithm is implemented using Fuzzy based techniques. The fuzzy scheduler used three matrics i.e. packet delivery ratio, Average end-to-end delay, and throughput. Triangular

membership functions have been used for proposed fuzzy schedules.

R.Senthil Kumaran (2012) proposed Fuzzy modified AODV (FMAR) routing protocol in MANET. This protocol is implemented using fuzzy inference system. Three input variables i.e. number of hop counts, sent controlled packets and energies of nodes on the routes are used for the output. Also a comparison of AODV and FMAR has been done successfully. For performance evaluation, network simulator-2 is implemented. In this work, implementation of AODV protocol with and without fuzzy logic for MANET has been done.

Pankaj Sharma (2012) *et al*. proposed a DSR Routing Decision technique for MANET. 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 analyzed.

Taqwa Odey (2011) *et al*. proposed a 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. 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.

3. Proposed Scheme

3.1 Extension to AODV

The AODV (Ad-hoc On-demand Distance Vector) routing Protocol uses an on-demand approach for finding routes, that is, a route is established only when it is required by a source node for transmitting data packets. It employs destination sequence numbers to identify the most recent path. The major difference between AODV and DSR stems from the fact that DSR uses source routing in which a data packet carries the complete path to be traversed. However, in AODV, the source node and the intermediate nodes store the next-hop information corresponding to each flow for data packet transmission. In an on-demand routing protocol, the source node floods the RREQ packet in the network when a route is not available for the desired destination. It may obtain multiple routes to different destinations from a single RREQ. The major difference between AODV and other on-demand routing protocols is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to the destination. A node updates its path information only if the*DestSeqNum* of the current packet received is greater than or equal to the last *DestSeqNum* stored at the node with smaller hopcount. A RouteRequest carries the *source* identifier (SrcID), the destination identifier (DestID), the source sequence number(SrcSeqNum), the destination sequence number (DestSeqNum), the broadcast identifier (BcastID), and the time to live (TTL) field. DestSeqNum indicates the freshness of the route that is accepted by the source. When an intermediate node receives a RREQ, it either forwards it or prepares a RREP if it has a valid route to the destination. The validity of a route at the intermediate node is determined by comparing the sequence number at the intermediate node with the destination sequence number in the RREQ packet. If a RouteRequest is received multiple times, which is indicated by the BcastID-SrcID pair, the duplicate copies are discarded. All intermediate nodes having valid routes to the destination, or the destination node itself, are allowed to send RREP packets to the source. Every intermediate node, while forwarding a RREQ, enters the previous node address and its BcastID. A timer is used to delete this entry in case a RREP is not received before the timer expires. This helps in storing an active path at the intermediate node as AODV does not employ source routing of data packets. When a node receives a RREP packet, information about the previous node from which the packet was received is also stored in order to forward the data packet to this next node as the next hop toward the destination. We have extended the RREQ packet by appending state information (including number of hops, bandwidth and packet loss rate at visited nodes) along with route record. Similarly, RREP is also appended with state information. The state information will assist the source node to verify QoS satisfaction of the intermediate nodes on the path. In our scheme, mobile agents perform the functions of RREQ and RREP packets.

3.2 Fuzzy Inference System Model

In fuzzy inference system, three input variables named number of hops, bandwidth, packet loss rate and one output variable delay is used.

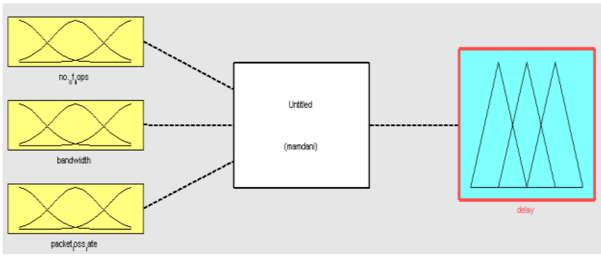

Fig. 1: FIS at Each Node

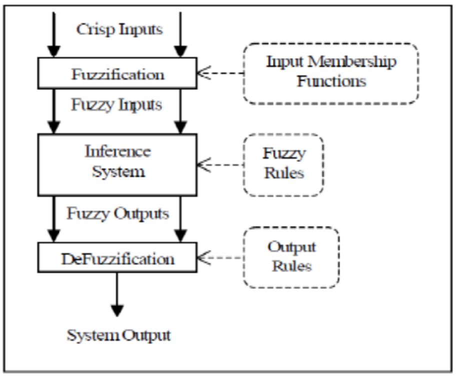

Fig.2: Steps in FIS

Mamdani method of fuzzy logic is used in our proposed technique. The implementation is based on following steps:
Step1: Fuzzification of the input variables number of hops, bandwidth, and packet loss rate -taking the crisp inputs from each of these and determining the degree to which these inputs belong to each of the appropriate fuzzy sets.
Step2: Rule evaluation taking the fuzzification inputs, and applying then to the antecedents of the fuzzy rules. It is then applied to the consequent membership function.
Step3: Aggregation of the rule outputs-the process of unification of the outputs of all rules.
Step4: Defuzzification-the input for the defuzzification process is the aggregate output fuzzy set chance and the output is a single crisp number.
Centre of gravity (COG) method is used for finding membership function. Using COG function, the aggregated points are fuzzified.

Neuro-fuzzy based Membership Function Optimization

We optimize selected membership function for fuzzy parameters bandwidth, packet loss rate and delay using neuro-fuzzy technique as per the requirement of source. The fuzzy membership functions can be any suitable parameterized functions such as triangular, trapezoidal or sigmoidal. The sigmoidal function is chosen in our scheme because of its continuous and differential property which is very suitable to apply back propagation learning algorithm in parameter optimizing phase.
The input fuzzy parameter considered are number of hops, bandwidth and packet loss rate . The output fuzzy parameter considered is delay. Fuzzy linguistic terms described for bandwidth are '*Low*', '*Medium*' and '*High*'; for packet loss rate; the terms are *'Less', 'Moderate' and 'More';* and for delay, the terms are *'Small' and 'Large';* for number of hops; the terms are *'Low'*, *'Medium'*, and *'High'* . The sigmoidal membership functions for the number of hops,bandwidth, packet loss rate and delay are shown in Figure . Neuro-fuzzy network employed for membership function optimization consists of five layers. First layer consists of input fuzzy variables bandwidth and packet loss rate; different linguistic terms of input variables form second layer; if-then fuzzy rules form third layer; fourth layer has fuzzy output linguistic terms and fifth layer is defuzzified output. Layers 2, 3 and layer 4 form hidden layers. The first layer has as many nodes (neuron) as the number of the independent fuzzy input variables. The second layer has one node for every fuzzy linguistic term of each of the input variables and those nodes are connected to the corresponding input node only. The third layer is to be used for learning significant AND combinations between the fuzzy labels from the second layer forming the fuzzy if-then rules. The number of nodes is the number of rules formed. The fourth layer consists of as many nodes as the number of the output fuzzy linguistic values. The fifth layer consists of as many nodes as the output fuzzy variable.

Neuro-fuzzy optimizes membership functions with two phases: (1) feed forward and (2) back propagation. These phases are repeated until optimized membership functions are obtained for the input and output fuzzy variables for the given requirement.

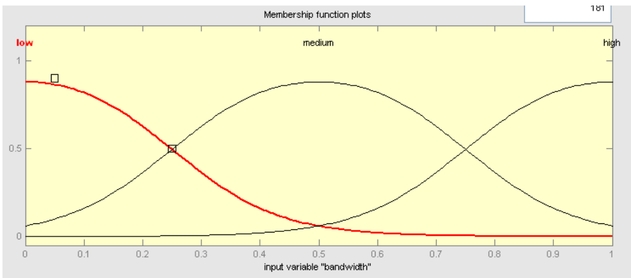

Fig.3: membership function for input variable 'bandwidth'

Fuzzy Rules
Rule No. 1: If no. of hops are Low and bandwidth is Low and packet loss rate is Less then delay is Large.
Rule No. 2: If no. of hops are Low and bandwidth is Low and packet loss rate is moderate then delay is small.
Rule No. 3: If no. of hops are Low and bandwidth is Low and packet loss rate is more then delay is Large.
Rule No. 4: If no. of hops are Low and bandwidth is medium and packet loss rate is Less then delay is small.
Rule No. 5: If no. of hops are Low and bandwidth is medium and packet loss rate is moderate then delay is small.
Rule No. 6: If no. of hops are Low and bandwidth is medium and packet loss rate is more then delay is Large.
Rule No. 7: If no. of hops are Low and bandwidth is high and packet loss rate is Less then delay is small.
Rule No. 8: If no. of hops are Low and bandwidth is high and packet loss rate is moderate then delay is small.
Rule No. 9: If no. of hops are Low and bandwidth is high and packet loss rate is more then delay is small.
Rule No. 10: If no. of hops are medium and bandwidth is Low and packet loss rate is Less then delay is Large.
Rule No. 11: If no. of hops are medium and bandwidth is Low and packet loss rate is moderate then delay is small.
Rule No. 12: If no. of hops are medium and bandwidth is Low and packet loss rate is more then delay is Large.
Rule No. 13: If no. of hops are medium and bandwidth is medium and packet loss rate is Less then delay is small.
Rule No. 14: If no. of hops are medium and bandwidth is medium and packet loss rate is moderate then delay is small.
Rule No. 15: If no. of hops are medium and bandwidth is medium and packet loss rate is more then delay is Large.

Rule No. 16: If no. of hops are medium and bandwidth is high and packet loss rate is Less then delay is small.
Rule No. 17: If no. of hops are medium and bandwidth is high and packet loss rate is moderate then delay is small.
Rule No. 18: If no. of hops are medium and bandwidth is high and packet loss rate is more then delay is small.
Rule No. 19: If no. of hops are high and bandwidth is Low and packet loss rate is Less then delay is Large.
Rule No. 20: If no. of hops are high and bandwidth is Low and packet loss rate is moderate then delay is Large.
Rule No. 21: If no. of hops are high and bandwidth is Low and packet loss rate is more then delay is Large.
Rule No. 22: If no. of hops are high and bandwidth is medium and packet loss rate is Less then delay is small.
Rule No. 23: If no. of hops are high and bandwidth is medium and packet loss rate is moderate then delay is Large.
Rule No. 24: If no. of hops are high and bandwidth is medium and packet loss rate is more then delay is Large.
Rule No. 25: If no. of hops are high and bandwidth is high and packet loss rate is Less then delay is small.
Rule No. 26: If no. of hops are high and bandwidth is high and packet loss rate is moderate then delay is Large.
Rule No. 27: If no. of hops are high and bandwidth is high and packet loss rate is more then delay is Large.

For simulation purposes, we have conducted a number of test cases, from which some are described in table 1.0.

Table 1: Test Cases

Test Case No.	No. of hops	Bandwidth	Packet loss rate	Delay
Test Case No.1	.0497	.52	.553	.334
Test Case No.2	.215	.524	.56	.555
Test Case No.3	.5	.51	.0762	.331
Test Case No.4	.5	.51	.526	.33
Test Case No.5	.00993	.0567	.0364	.666
Test Case No.6	.944	.93	.964	.666
Test Case No.7	.0629	.77	.56	.376
Test Case No.8	.0629	.243	.56	.382

In fig. 4, 5,6,7,8, and 9, in respect of three input variables named number of hop counts, bandwidth, packet loss rate, a single output delay has been shown using 3D surface viewer of fuzzy logic toolkit of MATLab 7.0.

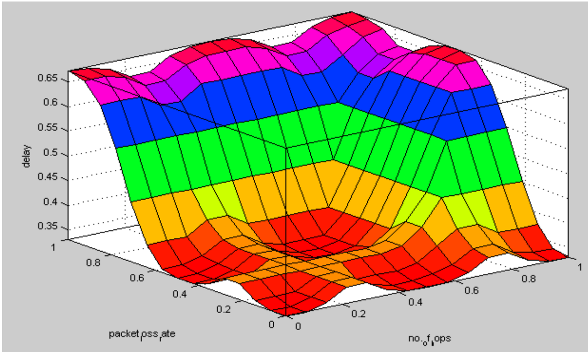

Fig.4: Output 'delay' w.r.t. input packet loss rate and no. of hops

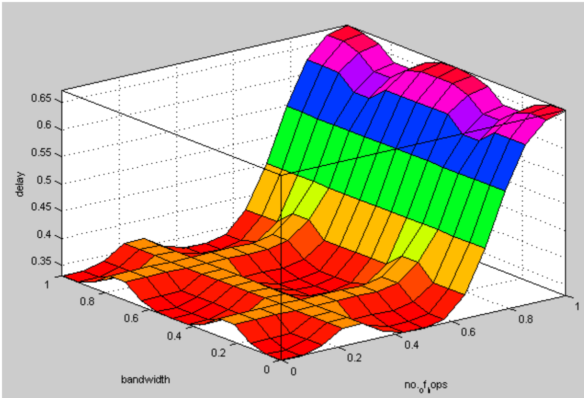

Fig.5: Output 'delay' w.r.t. input bandwidth and no. of hops

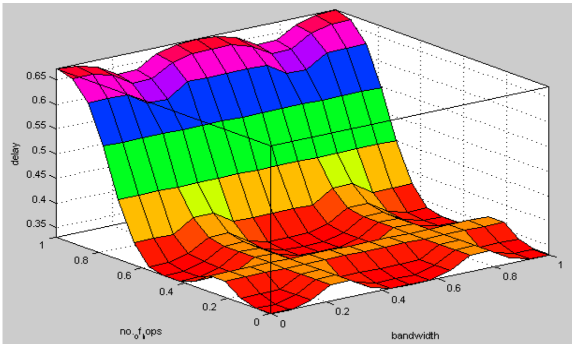

Fig.6: Output 'delay' w.r.t. input no. of hops and bandwidth

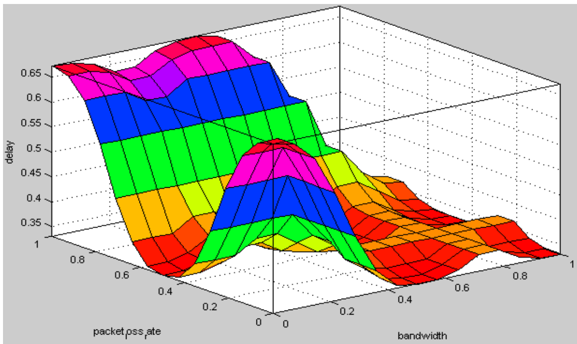

Fig.7 output 'delay' w.r.t. input packet loss rate and bandwidth

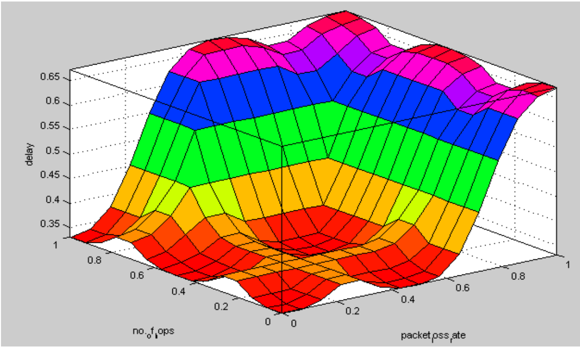

Fig. 8: Output 'delay' w.r.t. input no. of hops and packet loss rate

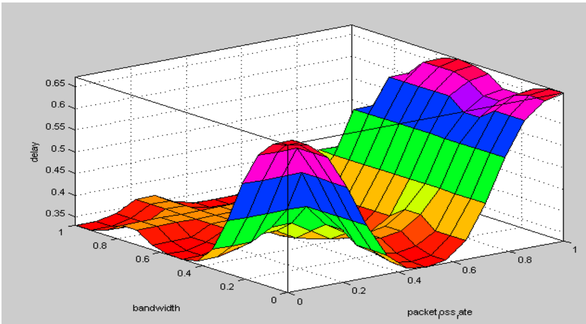

Fig. 9: Output 'delay' w.r.t. input 'bandwidth' and 'packet loss rate'

4. Agent based Model

Agent based model having four modules: i) User Agency ii) DSR Agency iii) QoS Agency iv) Common Knowledge Base (CKB). There are eight types' mobile and static agents in this model, which participate in finding QoS aware path for given source-destination pair and user requirement.

Software agents:

UMA-User Manager Agent, DMA-DSR Manager Agent, DSRA-DSR Agent, MA-Maintenance Agent, QMA- QoS Manager Agent, NFA- Neuro Fuzzy Agent, QA-QoS Agent, FQA-Fuzzy Q-Learning Agent

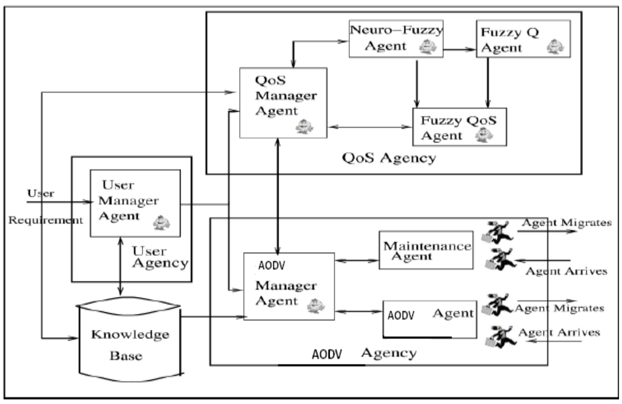

Fig.10: Agent based QoS Routing at Each Node

Steps in finding QoS aware path for given source - destination pair and the user requirement:

Step 1. User Manager Agent receives source address, destination address and QoS requirement.
Step 2. AODV Manager Agent receives source and destination address from User Manager Agent.
(a) AODV Manager Agent sends source and destination address to AODV Agent.
(b) AODV Agent finds all multi-paths and sends back to AODV Manager Agent.
Step 3. QoS Manager Agent receives source address, destination address and QoS requirement.
(a) QoS Manager Agent sends delay requirement to Neuro Fuzzy Agent to optimize membership functions.
(b) Neuro Fuzzy Agent replies optimized fuzzy membership functions to Fuzzy Rule Learning Agent and rules to QoS Agent.
(c) QoS Agent replies inferred fuzzy rules to Fuzzy Learning Agent.
Step 4. AODV Manager Agent sends all multi-paths to QoS Manager Agent to select QoS paths.
Step 5. Fuzzy Rule Learning Agent gets all multi-paths from QoS Manager Agent to decide whether node is QoS satisfied by using Optimized FIS.
Step 6. Fuzzy Rule Learning Agent decides the QoS node; if satisfied, considers next node on the path for verification until last node, else gets next path available for verification. Transmit data on the QoS satisfied path.
Step 7. AODV Manager Agent creates Mobile Agent which periodically checks for the failure of any node or link failure.
Step 8. Mobile Agent brings information of failure of node or link and AODV Manager Agent repairs the route.

Conclusions

This paper proposed an agent based QoS routing scheme for wireless mesh networks. We extended AODV protocol to find all the multi-paths and state information from source to destination. Fuzzy inference technique decides whether nodes on the path satisfy required delay. As decision is made by Fuzzy Inference Model and is dependent on the fuzzy membership functions and if-then rules; membership functions are optimized employing software agents. The proposed scheme effectively routes data packets to destination even in case of high mobility and link/node failures and has got good flexibility and adaptability. It improved the performance in terms of acceptance ratio, packet delivery ratio and latency.

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