Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.18576/amis/110213

Fuzzy Logic based Efficient Multipath Routing for Mobile Adhoc Networks

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Received: 2 Dec. 2016, Revised: 12 Jan. 2017, Accepted: 24 Jan. 2017
Published online: 1 Mar. 2017

Abstract: The reliable data delivery is the main problem of Mobile Ad-Hoc Networks (MANET). Due to node mobility, heavy packet dropping occurs, which leads to packet overhead and links break. The previous routing protocols are vulnerable to node mobility especially for large-scale networks. Due to this issue ,an Efficient Multipath Routing Protocol (EMRP) using fuzzy logic controller is proposed which takes advantage of the stateless property of geographic routing and the broadcast nature of wireless medium. In this protocol, both stability and mobility are calculated to determine network reliability. The reliable multipath is constructed based on network topology. Both link and node reliability is determined to enable novel routing based on calculation of stability. Fuzzy logic control procedure is implemented with reliability to increase the network performance. This system is used in ad hoc network to determine its reliability. The proposed protocol is simulated with Network Simulator (NS2.34) tool to attain better stability and network reliability and also improves the network life time compared to Existing protocols EMLARP.

Keywords: MANET; Node Mobility; Multipath Routing; Fuzzy Logic; Link stability; Network Reliability.

1 Introduction

Mobile ad hoc network (MANET) is a self configuring network where the mobile nodes are dynamically transmitting the packets in the absence of fixed based station or wireless backbone. It has been proved to be suitable for disaster applications. In these applications, first-aiders are engaged in rescuing activities and messages need to be sent to an entire network. To enable the communication in disaster scenarios. It supports network changes to minimize the packet loss.

A single destination recognizes the packet transmission to the set of hosts is called as multi pathing. In other words, it is the routing of packets to a group of destinations at the same time (Liu et al., 2008). Energy efficient multipath routing is used to connect multipath source and destinations with maximum durability and less energy consumption. Multipath routing problem is the major issue in communication network. It demands the source and a set of destinations to be connected with less cost function.

The existing multipath protocols of MANET have their own advantages and disadvantages (Nasehi et al., 2013).The advantages of overlay multipath are the robustness and the low overhead. But it uses unicast forwarding to send the packets. The total energy consumption or system lifetime of the multipath tree can be optimized by means of Energy aware multipath protocol (Aquino-Santos et.all. 2015).

1.1 Issues in Designing a Multipath Routing Protocol

The major issue in multipath routing is to determine appropriate multipath group members in order to transmit packets between multipath source and destinations (Liu et al., 2009).However, the load balancing and network resources utilization along with other QoS parameters have to be considered. In several multipath routing approaches, the details of group members are stored in routers. However, it produced high delay and these approaches were not able to support node mobility (Kashyap & Rathy R.K.,2012). Multipath service in MANET should offer flawless and integrated operation in spite of nodes mobility.

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MANET unique characteristics have posed new challenges in multipath routing protocol design (Varun& Gajendra., 2013).Such as dynamic network topology, energy constraints, lack of network scalability and a centralized entity. The different characteristics posed the challenges such as limited bandwidth and poor security.

2 Related Work

Das et.all (2015) proposed the fuzzy cost based Multi Constrained Quality of Service Routing for optimal path selection based on bandwidth, end to end delay and number of intermediate hops. The path with maximum lifetime and minimum fuzzy cost was considered for best transmission. There was no stability of link present in this work.

Singh et.all (2015) establish the fuzzy based intelligent agent routing to find packet loss rate, optimal parameters, membership functions and repairing of path broken. Reliability inclusion was avoided in this work. Link connectivity was also not maintained in this routing.

Sju et.all (2014) developed the multipath communication and location of mobile nodes was updated by kalman filter mechanism. The efficiency of the future cluster had also been determined with fuzzy clustering. Here there was no determination of cluster head node stability and the calculation of cluster head election reliability.

The fuzzy based multi-path energy aware QoS routing was proposed by Ali&Fahad (2016) to join uncertain metrics such as bandwidth, link delay, and energy and packet loss rate. The main purpose of this work was to choose path and satisfy QoS criteria. Depending on link reliability only, packet loss rate can be successfully reduced.

The fuzzy logic control with mesh based routing protocol was implemented by Rajashekhar et.all (2010) to get the information about battery status and link quality. The next goal was the overhead reduction with join query flooding packet. The limitation of this work is that link stability is not maintained during packet transmission phase. It will lead to heavy packet loss and more overhead.

Wang&Huang (2007) proposed the fuzzy logic based Rate Control8 to handle simultaneous traffic [FB02?]ows without dominating the available bandwidth of networks. It was found that high congestion during heavy traffic flow occurs. This work will not be suitable for real time traffic sessions.

A new routing technique was developed based on mobility, throughput and bandwidth (Natsheh et.all., 2006). Various optimization techniques were also suggested to provide stability index in this routing. But there was no proven model for stability in this work.

Fuzzy based Reliable Multipath Routing Approach to ensure reliability requirements (Sethi&Udgata., 2011). Protection based Approach was also developed to satisfy the reliability requirements. This reliability was not integrated in MANET in real time traffic scenarios.

Santhi& Nachiappan(2011) proposed the fuzzy scheduler that found the priority index of the queued packets. It combines the input parameters such as data rate, expiry time, and queue length for finding the priority index. Without fuzzy scheduling the packets are scheduled in first in first out. Here the software agents were used for both in routing and fuzzy priority scheduling stages. Agents will lead to unreliability of the network.

S.Gupta et.all(2011) proposed a new technique multipath tree based on spanning tree concept while employing a fuzzy controller. It used three inputs namely link bandwidth, link delay and link reliability for multipath tree construction.

The Adaptive Fuzzy Logic Based Security Level Routing to secure end to end protocol to discover the secure multipath route (Pi&Sun., 2012). Only secure routes were focused. There is need to focus on stability with reliable multipath route.

Location management and future cluster head prediction method based on adaptive fuzzy system to ensure less overhead for route maintenance (Yuste et.all., 2013). Sometimes the location of mobile nodes may be out of the range and it is difficult to predict clustering in future.

In this paper (Ali et.all., 2015) Fuzzy based multipath load and energy routing protocol was introduced for reliability of cluster based mesh, safety of multipath delivery and QoS provision. Its used to achieve energy consumption of the mobile node and path.It was integrated with mesh topology which leads to heavy flooding and overhead.

In this paper (Vinoth&Bhavani., 2015) author proposes efficient multipath location aware routing. The cluster enhanced multipath routing is proposed to overcome the problem of network unbalancing and node failures. Multipath routing is predicted and route request messages are broadcasted to attain set of node disjoint paths. The location updation of mobile node to achieve high packet delivery rate.

In our approach, our protocol is able to adopt in any scale networks and withstand any attackers and failures of network components and achieve reliable multipath routing which enhances the stability and reliability of the network.

The research paper is organized as follows. The Section 1 describes introduction about manet and multipath routing, Section 2 deals with the previous work which is related to the Fuzzy based multipath routing algorithms. Section 3 is devoted for the implementation of proposed scheme. Section 4 describes the performance analysis and the last section concludes the work.

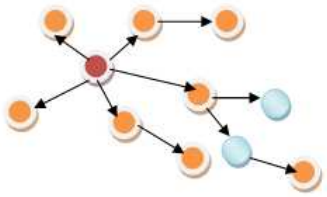

Fig.1. Multipath Routing Approach for EMRP

3 Fuzzy Logic Based Efficient Multipath Routing Protocol

The main aim of the proposed Efficient Multipath Routing Protocol (EMRP) is to focus on network reliability based on node reliability and link stability calculations. In first step, we designed a multipath backbone network model. If the primary path fails in a network, alternate paths are chosen based on the routing table. It supports to improve network performance and reliability. The figure 1 shows the multipath routing approach in EMRP.

In general, reliability is measured in terms of mobility of nodes and energy efficiency. In our work, reliability includes stability and mobility of nodes as well as links. Before the route discovery process begins, link stability is an important issue to consider. Link reliability ensures whether stability of link exists or does not exist. Node reliability is determined based on packet loss rate, packet delay, throughput, packet delivery rate. In general, congestion occurs due to non reliability of nodes. To avoid this, stability of node is maintained during route discovery and route maintenance phase. If any stale routes found, it will be immediately removed with proposed routing protocol.

Fuzzy logic control is enabled for reliable routing to overcome the issues of uncertainty of proposed protocol. Reliability is ensured by fuzzy control process to constantly improve network lifetime. Decision process is derived from defuzzification to determine whether network is reliable or not. It is based on two inputs to the fuzzification module i.e. node reliability and node reliability. The network reliability is represented by the fuzzy logic controller which is shown in Fig. 2

In MANET, reliability is the measure of successfully received the packets at the destination from the source node with more stability of links and nodes.

The following assumptions are made to simplify the analysis and focus on some key factors.

1. Source node and Destination node are kept static and constant.
2. Nodes are moving within the transmission range.
3. Every node keeps the constant and same data transmission with each of its neighbor nodes.
4. All the links are binary which means the link exists or does not exist.

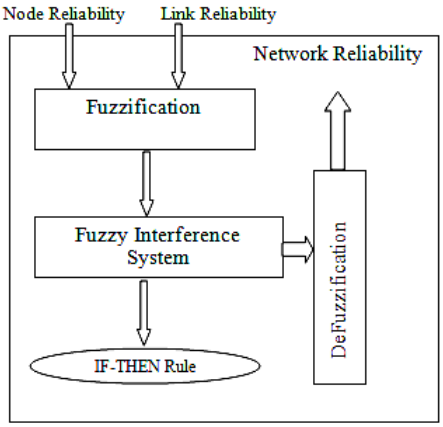

Fig.2. Fuzzy Logic Controller

5. Both Stability and Mobility are calculated to ensure reliability of the network.

3.1 Determination of Node Reliability

The node reliability is calculated as the probability of a message to successfully reach the destination node from the source node. The node Stability and Mobility are used o find the node reliability.

Node stability rate ($N_{sr}(t)$) is related to the mobility and energy dissipation of the nodes. It combines mobility rate, energy rate and energy wasted on packet loss of the nodes. Mobility rate is calculated from the Link Expiration time, which is estimated as,

$$LET = \frac{-(uv+xy)+\sqrt{\{(u^2+x^2)d^2-(uy-xv)^2\}}}{u^2+x^2} \quad (1)$$

Where $u = v_a Cos\theta_a - v_b Cos\theta_b$

$v = L_a - L_b$, $x = v_a Sin\theta_a - v_b Sin\theta_b$

$y = M_a - M_b$

Here d is the transmission distance between the mobile nodes a and b. (La, Ma) and (Lb, Mb) be the coordinates. (va, θ a) and (vb, θ b) be the (velocity, direction) of motion of nodes.

Energy Rate is defined as the energy dissipation of the mobile nodes which is calculated from Drain Ratio (DR). Actual drain ratio is calculated from the old and new values of DR.

$$DR_a = \alpha DR_{old} + (1-\alpha)DR_{new} \quad (2)$$

Where 0< α <1, indicates updated information is high. If the depletion ratio is faster, the node is highly depleted for its energy.

Node Stability rate is given as,

Nsr(t) =Mobility Rate+ Energy Rate-Energy Wasted on packet loss

The node reliability is formalized as

$$R_k = (1 - \tanh\chi(f_k - \delta)) \times \gamma + Nsr(t) \qquad (3)$$

R_k is the node reliability of the node k. $\chi, \delta, \varepsilon$ are the coefficients which is are related to the type of wireless devices, packet size and packet sending rate. f_k is the number of the neighbor nodes. Nsr(t) is the Link Stability rate.

3.2 Link Stability Determination

Link Stability ratio indicates that relative stability of path between the source and distance nodes. If any one of the link that builds up path is broken, the path is also broken. But the status of one link in the path is independent of another links. For the path K, the probability that a path is non-broken equals to the product of probabilities that its links are non broken. The Link Stability ratio of K at time t, $S_k(t)$ is defined as,

$$S_k(t) = S_{e,l_1(t)} \times \prod_{v=1}^{m-1?} S_{e_v,l_{v_{+1}}}(t) \times S_{e_m,d}(t) \qquad (4)$$

3.3 Proposed packet format

In fig.3 the proposed packet format of EMLARP is shown.

Here the source and destination node ID carries 2 bytes. The third field hop count determines the number of nodes connected to the particular node in the region. It occupies 4 byte. The node stability rate of 4 bytes size indicates whether it is decreased from threshold vector value. Status of network reliability is verified during the route maintenance phase. It occupies 4 bytes. The last filed FCS i.e. Frame Check Sequence which is for error correction and detection in the packet during transmission carries 2 bytes.

4 Performance Evaluation

We use Network Simulator (NS2.34) to simulate our proposed Efficient Multipath Routing Protocol (EMRP).NS2 is one of the best simulation tools available for Wireless ad hoc Networks. We can easily implement the designed protocols either by using the otcl coding or by writing the C++ Program. In either way, the tool helps to prove our theory analytically. In our simulation, 200 mobile nodes move in a 1200 meter x 1200 meter square region for 60 seconds simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).

Our simulation settings and parameters are summarized in table 1.

Table.1. Simulation and Settings parameters.

No. of Nodes	200
Area Size	1200 X 1200 sq.m
Mac	802.11
Radio Range	250m
Simulation Time	60 sec
Traffic Source	CBR
Packet Size	512 bytes
Mobility Model	RWP
Initial energy	85 J
Transmitted power	0.8 watts
Received Power	0.08 watts

4.1 Performance Metrics

We evaluate mainly the performance according to the following metrics.

Average Packet Delivery Ratio: The packet delivery ratio (PDR) is estimated based on equation given below:

$$PDR = \frac{\text{Number of Packets Received}}{\text{Number of Packets Transmitted}}$$

Node degree: It is defined as the performance matrices of the network topology.

Network connectivity ratio: It is defined as the ratio for numbers of nodes are connected in the intermediate region.

Network Stability Rate: Link stability rate means the capacity and lifetime of link exists in the network.

Network Reliability Rate: It is the combination of node reliability rate and link reliability rate. Node reliability rate means nodes which are genuine through the entire communication process. Link reliability rate means the fault tolerance of link which reaches within the transmission range.

Control Overhead: The control overhead is defined as the total range of routing control packets normalized by the overall range of received information packets.

End-to-end delay: It depends on the routing discovery latency, extra delays at every hop. It's normalized by means of control packets.

4.2 Results

We compared our proposed protocol EMRP with Existing protocol EMLARP (Vinoth&Bhavani., 2015).

Figure 4 shows the results of connectivity ratio versus mobility. From the simulation results proposed scheme has higher connectivity ratio than the Existing method. Our proposed scheme EMRP has high link reliability rate and also high network stability rate.

Figure.5, presents the results of node degree versus speed. It is clearly shown that the proposed scheme has

Source ID	Destination ID	Location update status	Link Stability rate	Network Reliability Status	FCS
2	2	4	4	4	2

Fig.3. Proposed Packet format.

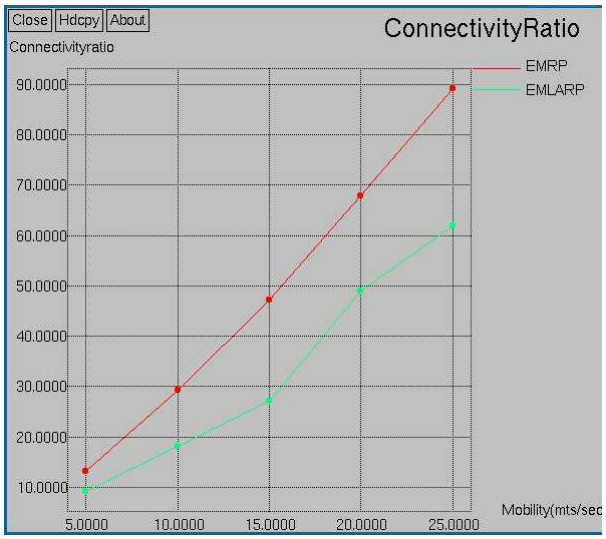

Fig.4. Mobility Vs Connectivity Ratio

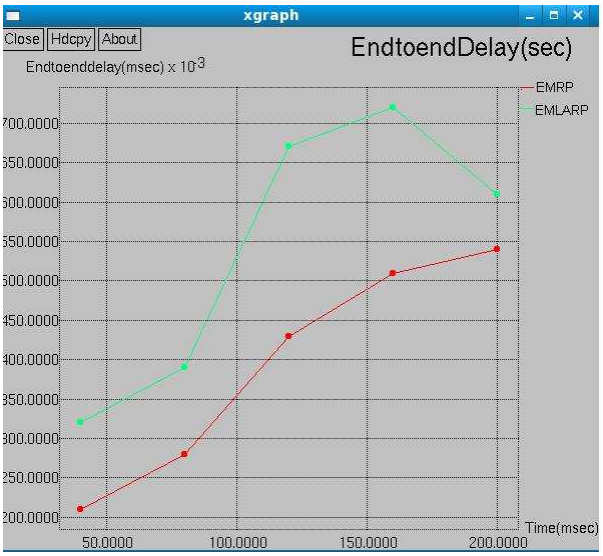

Fig.6. Time Vs End to end delay

less node degree. Therefore proposed scheme has less packet loss compared to existing scheme.

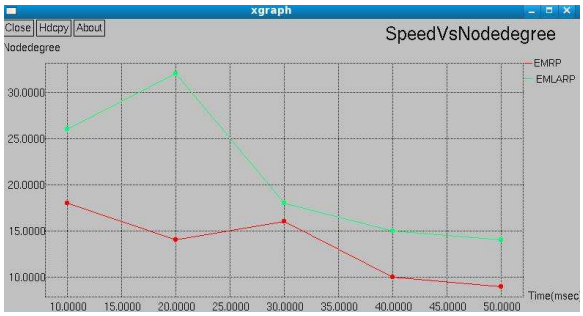

Fig.5. Speed Vs Node degree.

Figure 6 shows the results of Time Vs End to end delay. Mobility is varied as 10, 20. . . .100 kbps. From the simulation result EMRP has fewer packets propagating delay and low end to end delay than the existing routing schemes.

Figure.7 shows the simulation result of number of nodes versus communication overhead. If only the control packets are continuously transmitting, the packet overhead will get increases. Link capacity is not that enough to transmit more control packets in previous work. In our proposed model, we schedule the packets through link. Accordingly, packets are arrived at the destination. The problem of congestion overflow and packet dropping is decreased. So the proposed scheme achieves less communication overhead than the EMLARP method.

In figure.8 shows the result of simulation time Vs Packet Delivery Ratio. From the results, EMRP has high packet delivery ratio than the EMLARP. So Packet arrived at the destination node is high. Link between the nodes are well connected together to avoid congestion. So the proposed protocol to ensures reliability of node and link.

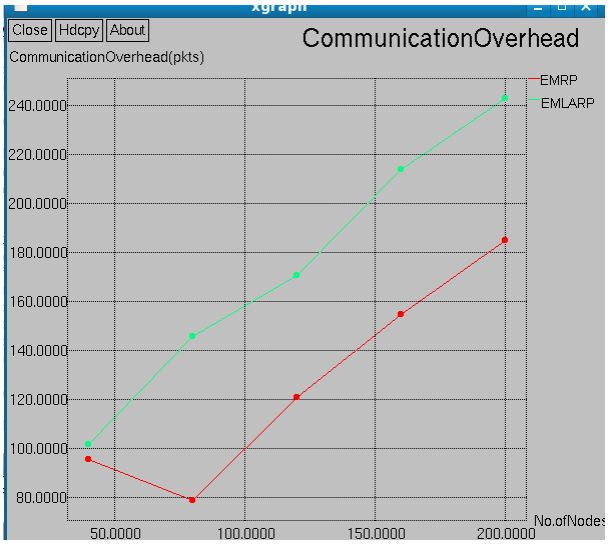

Fig.7. No. of Nodes Vs Overhead

Table 2. Simulation and Settings parameters.

Metrics	EMLARP	EMRP
Detection efficiency (%)	25-35	46-52
PDR (pkts)	15-23	35-47
Network L_time (Secs)	100-147	223-340
End to end delay (msec)	0.678-1.47	0.298-0.36
Overhead (pkts)	47-56	28-37
Node Reliability (Node/Secs)	49-64	75-87
Link Stability (Sec)	41-52	62-74
Packet loss rate (Pkts/Secs)	25-37	17-22

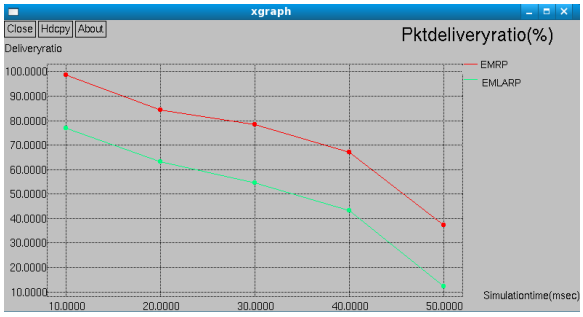

Fig.8. Throughput Vs Packet Delivery Ratio

The table.2 shows the simulation result analysis of the proposed scheme EMRP and existing scheme EMLARP.

From the various simulation results the proposed scheme (EMRP) has high connectivity ratio, low end to end delay, less packet loss rate, high PDR, high network life time and also attains better stability and network reliability compared to the previous scheme EMLARP.

5 Conclusions and Future Work

In this research work, the Fuzzy based reliable multipath routing protocol is proposed for handling link, node failures and malicious attackers in ad hoc networks. The proposed scheme (EMRP) is to maintain the reliable multipath routing which enhances the stability and mobility of the network. Fuzzy based reliable routing is determined to ensure conditional based reliability. Reliable multipath routing is determined towards high packet delivery rate and improves the network life time. Based on evaluation of the simulation results, the performance of the proposed protocol is better previous work in presence of uncertainty cases. The proposed work can be a suggestive approach for a real life approach such as military search and rescue operations.

In future, we have planned to implement cryptographic based secured reliable routing to achieve secure data transmission and reliable data delivery.

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