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Fuzzy Based Mobility and Energy Aware QoS Routing Protocol for Hybrid Wireless Networks

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Abstract: In hybrid wireless networks, the process of scheduling the packets to the forwarding node is difficult owing to the node mobility and large packet size factors. Also, the energy consumed during this process is increased. Hence in order to overcome this issue, in this study, we propose a fuzzy based mobility and energy aware QoS routing protocol for hybrid wireless networks. In this protocol, the Link Expiration Time (LET), Residual Energy (RE) and Received Signal Strength (RSS) of a node are estimated. The packets are classified based on the deadline and packet size. The scheduling probability of node is estimated using fuzzy logic technique based on the parameters that includes load, space utility, RE, LET and RSS. Further, depending on the category of the packet, the corresponding forwarding node is assigned based on the estimated scheduling probability. By simulation results, we show that the proposed technique reduces the energy consumption and traffic load.

Key words: Hybrid wireless networks, QoS, packet size, energy consumption, node mobility, India

INTRODUCTION

Hybrid manet: Mobile Adhoc Network (MANET) is a collection of independent mobile nodes that communicate with each other via radio waves (Mangai and Tamilarasi, 2010). The mobile devices or nodes are communicating with peer-to-peer connection (Nivetha *et al*., 2013). A mobile devices are a self-organized and self-controlled network, they do not rely on any infrastructure or centralized server. MANET used to access the global services from the Internet and to widen the coverage area (Majumder *et al*., 2011). The characteristics of MANETs are distributed structure, changing topology and limited battery life at each node (Ito *et al*., 2013). Applications of MANET includes emergency and rescue operations, conference or campus settings, body area and personal networks or vehicular networks (Whitbeck and Conan, 2010).

The interconnection of mobile ad hoc networks (MANETs) to Internet is an attractive demand of increasing ubiquitous computing which is called hybrid or connected MANET (Vaidya *et al*., 2008). This heterogeneous network is formed by the interconnection of the wired internet and the wireless mobile ad hoc network. Heterogeneous wireless networks are intended as an integral component of the future 4G networks (Zaman *et al*., 2012). By interconnecting MANET with Internet, people will expect widening the wireless application space and making worldwide network seamless (Zhuang *et al*., 2009).

In order to enhance the reliability and robustness of the interconnection between MANET and the Internet, multiple gateways are usually deployed in these hybrid networks, such as proactive, reactive and hybrid (Yan *et al*., 2014). In the proactive gateway discovery approach, the gateway transmits gateway advertisement messages to mobile nodes. In the reactive gateway discovery approach, the mobile nodes broadcasts a gateway solicitation message for desired Internet connectivity. In the hybrid approach, mobile nodes in a part of the mobile ad hoc network use the proactive approach and the rest of the nodes use the reactive approach (Zaman *et al*., 2012). The Internet Gateway (IGW) can provide Internet connectivity for nodes in the MANET. It is located at the edge of MANET and has a connection to both the Internet and the MANET (Zhuang *et al*., 2009). However, there are several issues to be addressed in hybrid MANET:

- Bandwidth efficiency
- Traffic concentration effect
- Dynamic change in gateway node
- Heterogeneous gateway
- Quality of Service provisioning (Yan *et al*., 2014; Zheng *et al*., 2014a, b)

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QoS routing in Hybrid MANET: Routing is an important aspect in mobile ad hoc Network MANET as all network activity including discovering the topology and delivering messages needs to be carried out by the nodes themselves. Routing protocol determines secure path to send data packets from a source node to a destination node (Mangai and Tamilarasi, 2010).

Quality of Service (QoS) routing is a key network function for the transmission and distribution of digitized audio /video across next-generation high-speed networks. QoS is to define a level of performance in a communications network along with the type of network traffic. QoS requirements are present in many network situations, such as in critical infrastructure control and military communication. Effective mobile ad hoc networks require QoS capabilities that provide fault tolerance and fast recovery when links fail on an intermittent or permanent (Oikonomou *et al*., 2011).

QoS guarantees to support real time and multimedia applications in MANET. The QoS constraints can be classified as time constraints, space constraints and frequency constraints. Effective mobile ad hoc networks (MANETs) require QoS capabilities that provide fault tolerance and fast recovery when links fail on an intermittent or permanent basis (Su *et al*., 2014). The major objectives of QoS routing are:

- To find a path from source to destination satisfying user's requirements
- To optimize network resource usage
- To degrade the network performance when unwanted things like congestion, path breaks appear in the network

The main problem to be solved by QoS routing algorithm is the Multi-Constraint Path problem (Deepalakshmi and Radhakrishnan, 2009). QoS Routing considers bandwidth constraint, delay constraints or both but don't meet these constraints while optimizing the overall network throughput. The notion of QoS is guarantee provided by network to satisfy a set of predetermined service performance constraints for the user in terms of the end-to-end delay statistics, available bandwidth and probability of packet loss and call admission delay (Gnanamurthy *et al*., 2006).

However, these QoS routing algorithms cannot be applied directly to Ad-hoc networks because of the bandwidth constraints and dynamic network topology of Ad-hoc networks.

Problem Identification: In a QoS Oriented Distributed routing protocol (QOD) for hybrid networks was proposed (Shen, 2010). It consists of QoS oriented neighbour selection algorithm, distributed packet scheduling algorithm, mobility based segment resizing algorithm, traffic redundant elimination algorithm and data redundancy elimination-based transmission algorithm. In QoS oriented neighbour selection algorithm, the neighbours are selected based on the deadline requirements and work load. But apart from delay and work load, communication delay occurs due to bad channel condition or link quality. Moreover, the energy expenditure of packet scheduling should be considered. So, the neighbour selection should also include the link quality and residual battery power metrics.

In mobility based packet resizing algorithm, larger sized packets are assigned to lower mobility intermediate nodes and smaller sized packets are assigned to higher mobility intermediate nodes. But it will be challenging to estimate the node mobility while scheduling the dead-line driven packets. Moreover, if lower mobility intermediate nodes could not be find out, then assigning large sized packets will become a problem.

Literature review: Li and Shen (2010) have proposed a QoS Oriented Distributed routing protocol (QOD) for hybrid networks. QOD consists of 5 algorithms:

- QoS oriented neighbour selection algorithm to meet the transmission delay requirement
- Distributed packet scheduling algorithm to further reduce transmission delay
- Mobility based segment resizing algorithm hat adaptively adjusts segment size according to node mobility in order to reduce transmission time
- Traffic redundant elimination algorithm to increase the transmission throughput
- Data redundancy elimination-based transmission algorithm to eliminate the redundant data to further improve the transmission QoS

Llewellyn *et al*. (2011) have proposed a cluster-based QoS routing algorithm for mobile ad hoc networks with the aim of providing fault tolerance which is a critical feature in providing QoS in the link failure-prone environment of mobile networks. Performance of this new fault-tolerant cluster-based QoS wireless algorithm is evaluated according to failure recovery time, dropped packets, throughput and sustained flow bandwidth. However, the failure rate increases more than twice for the rate of increase for mean recovery time.

Hanzo and Tafazolli (2011) study proposed and evaluated a new protocol for improving the performance (QoS guarantees) of QoS-aware routing and admission control protocols in the face of mobility, shadowing and varying link SINR. It is found that proactively maintaining backup routes for active sessions, adapting transmission rates and routing around temporarily low- SINR links can noticeably improve the reliability of assured throughput services. But with the severe shadowing fluctuations, the parameter does not have much effect because pretested backup routes often break before they come into use.

Su *et al*. (2014) study analysed the designs methods for bandwidth estimation and allocation to provide QoS support without knowledge of slot status information and then, estimates and allocates non-assigned eligible bandwidth for Best Effort (BE) flows. With these bandwidth management methods, this study proposed a QoS routing protocol for a mixture of QoS and BE flows. Also this study considered the problem of joint Topology Transparent Scheduling (TTS) and quality-of-service (QoS) routing in ad hoc networks and presents a joint scheme for the problem.

Sun *et al*. (2013) have proposed a novel randomized protocol FRIEND which is a pre-handshaking ND protocol to initialize synchronous full-duplex wireless ad hoc networks. By introducing a pre-handshaking strategy to help each node be aware of activities of its neighbourhood which significantly reduce the probabilities of generating idle slots and collisions. Moreover, with the development of single-channel full-duplex communication technology, third protocol further decrease the processing time needed in FRIEND and construct the first full-duplex ND protocol. However, the duty cycle of transmission is very poor when the packet send to subset will wait for transmission.

MATERIALS AND METHODS

Overview: In this study, we propose to develop a mobility aware distributed routing protocol. In this protocol, the Link Expiration Time (LET), Residual Energy (RE) and Received Signal Strength (RSS) of a node are estimated. Then the packets are classified into the following categories:

- Hard deadline with larger size
- Hard deadline with smaller size
- Soft deadline with larger size and
- Soft deadline with smaller size

Then parameters load, space utility, RE, LET and RSS are used as input for fuzzy logic and the scheduling probability of the forwarding node is estimated as output of the fuzzy rules. Then depending on the category of the packet, the corresponding forwarding node is assigned based on the estimated scheduling probability.

Estimation of metrics

Load: Load (L(i)) refers to the traffic density of node i which is the sum of traffic queue of node and the traffic queue of all its neighbours:

$$L(i) = l_i + \sum_{\forall j \in N(i)} l_j \tag{1}$$

Where:

N(i) = The neighbourhood of node i
l_i = The size of the traffic queue
L_i = Traffic density of node i

Space utility: The space utility is the function of number of used slots, number of unused slots and number of slots having collision which is estimated using the following Eq. 2:

$$CU_i = \frac{N_{US} - N_{CS}}{N_{TS}} \tag{2}$$

Where:

N_{US} = The number of used slots in active period. (The nodes Active period is the duration when the data packet is transmitted or subjected to collision)
N_{CS} = The number of slots comprising collision
N_{TS} = The total number of contention access slots during active period

Residual energy: Let E_i be the initial energy of a node After the time period t, the energy consumed by the node (E (t)) is given using following Eq. 3:

$$E(t) = n_{tx} \times \varepsilon + n_{rx} \times \delta \tag{3}$$

where: n_{tx} and n_{rx} are the number of data packets transmitted and received by the node after time t. ε and δ are constants in the range (0,1). The residual energy (E_r) of a node at time t is computed using the following Eq. 4:

$$E_r = E_i - E(t) \tag{4}$$

Link expiration time: It is defined as the ratio of the number of data packets to be sent to the number of data packets to be send per second:

$$LET = \frac{\text{No of packets to be sent}}{\text{No of packets to be send per second}} (\text{sec}) \tag{5}$$

Received signal strength: Link quality indicator is defined as the characterization of strength and/or the quality of a received packet. It is directly proportional to Received Signal Strength (RSSI). Its value varies from 0-255:

$$\text{LQ} \propto \text{RSSI} \tag{6}$$

RSSI is the ratio of the received power (P_{rx}) to the reference power (P_r) In general, P_r is equivalent to absoulte value say 1mW:

$$\text{RSSI} = 10.\ \log \frac{P_{rx}}{P_{ref}}(\text{dBm}) \tag{7}$$

When P_{rx} increases, then RSSI value is also increased which in turn enhances the link quality.

Packet classification: In our technique, we consider the following packets categories:

- Hard deadline with larger size
- Hard deadline with smaller size
- Soft deadline with larger size and
- Soft deadline with smaller size

Fuzzy based mobility and energy aware qos routing protocol: During data transmission, the Scheduling Probability (SP) of the forwarding node is estimated using fuzzy logic. The node parameters such as load, space utility, residual energy, link expiration time and received signal strength are considered as inputs parameters. The input parameters are fuzzified to make fuzzy decision rules and based on the outcome of the rules, i.e., scheduling probability is estimated. The steps that determine the fuzzy rule based interference are as follows:

- Fuzzification; this involves obtaining the crisp inputs from the selected input variables and estimating the degree to which the inputs belong to each of the suitable fuzzy set
- Rule Evaluation; the fuzzified inputs are taken and applied to the antecedents of the fuzzy rules. It is then applied to the consequent membership function.
- Aggregation of the rule outputs; this involves merging of the output of all rules
- Defuzzification; the merged output of the aggregate output fuzzy set is the input for the defuzzification process and a single crisp number is obtained as output. The fuzzy inference system is illustrated using Fig. 1

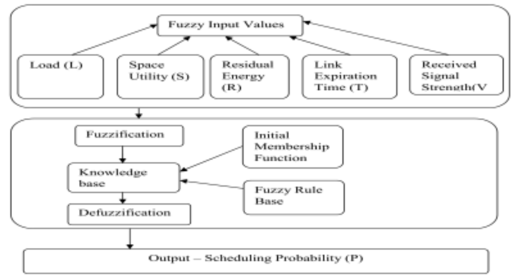

Fig. 1: Fuzzy inference system

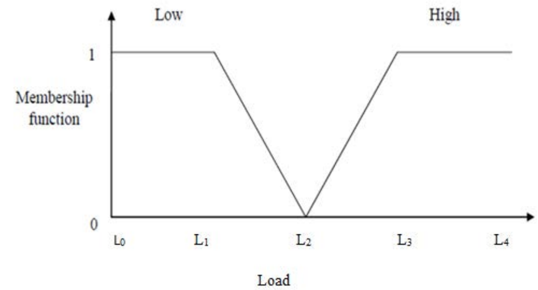

Fig. 2: Membership function of load

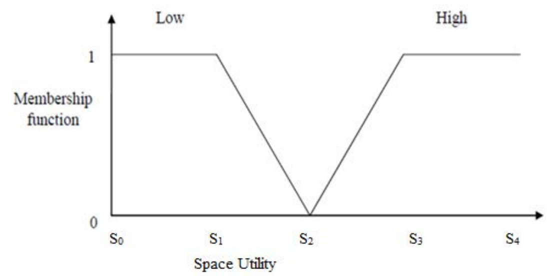

Fig. 3: Membership function of space utility

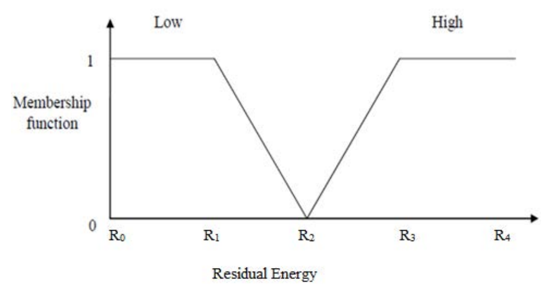

Fig. 4: Membership function of residual energy

Fuzzification: This involves fuzzification of input variables such as Load (L), Space utility (S), Residual energy (R), link expiration Time (T), received signal strength (V) and these inputs are given a degree to appropriate fuzzy sets. The crisp inputs are combination of L, S, R, T and V. We take two possibilities, high and low for L, S, R, T and V. Figure 2-7 shows the membership function for the input and output variables. Due to the computational .

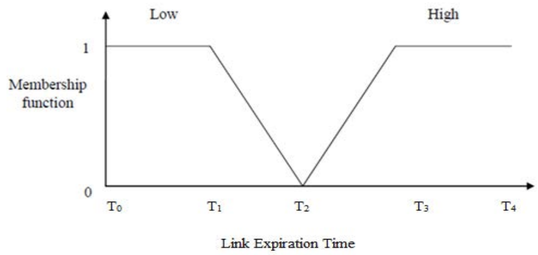

Fig. 5: Membership function of link expiration time

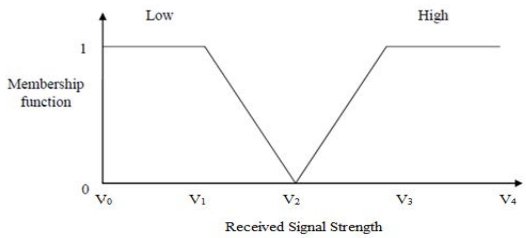

Fig.6: Membership function of received signal strength

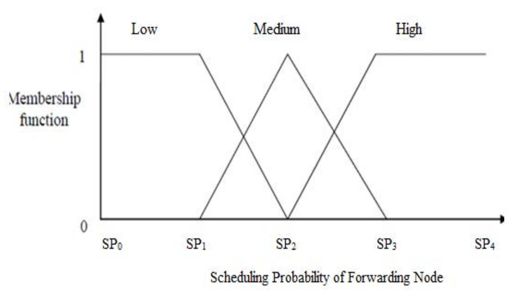

Fig. 7: Membership function of scheduling probability of forwarding node

efficiency and uncomplicated formulas, the triangulation functions are utilized which are widely utilized in real-time applications. Also a positive impact is offered by this design of membership function. In table 2, L, S, R, T and V are given as inputs and the output represents the combined score. The fuzzy sets are defined with the combinations presented in Table1.

Table 1 demonstrates the designed fuzzy inference system. This illustrates the function of the inference engine and method by which the outputs of each rule are combined to generate the fuzzy decision. For example;

Algorithm A

Let us consider Rule 16
If (S, R,T and V = High) and (L = low)
Then
SP = High.
The node with maximum scheduling probability is assigned for performing forwarding operation based on the packet category.
End if

Table 1: Fuzzy rules

Load (low)	Space utility (High)	residual energy (High)	Link expiration time (High)	Received signal strength (High)	Scheduling probability
Low	Low	Low	Low	Low	Low
Low	Low	Low	Low	High	Low
Low	Low	Low	High	Low	Low
Low	Low	Low	High	High	Low
Low	Low	High	Low	Low	Low
Low	Low	High	Low	High	Low
Low	Low	High	High	Low	Low
Low	Low	High	High	High	Low
Low	High	Low	Low	Low	Low
Low	High	Low	Low	High	Low
Low	High	Low	High	Low	Low
Low	High	Low	High	High	Medium
Low	High	High	Low	Low	Low
Low	High	High	Low	High	Medium
Low	High	High	High	Low	Low
Low	High	High	High	High	High
High	Low	Low	Low	Low	Low
High	Low	Low	Low	High	Low
High	Low	Low	High	Low	Low
High	Low	Low	High	High	Medium
High	Low	High	Low	Low	Low
High	Low	High	Low	High	Low
High	Low	High	High	Low	Medium
High	Low	High	High	High	High
High	High	Low	Low	Low	Low
High	High	Low	Low	High	Low
High	High	Low	High	Low	Low
High	High	Low	High	High	High
High	High	High	Low	Low	Low
High	High	High	Low	High	Medium
High	High	High	High	Low	Medium
High	High	High	High	High	High

Table 2: Assignment of forwarding nodes

Deadline	Packet size	Forwarding node Assignment
Hard	Large	High scheduling probability
Hard	Small	Medium scheduling probability
Soft	Large	Low scheduling probability
Soft	Small	Low scheduling probability

Defuzzification: The technique by which a crisp values is extracted from a fuzzy set as a representation value is referred to as defuzzification. The centroid of area scheme is taken into consideration for defuzzification during fuzzy decision making process. Equation 8 describes the defuzzifier method:

$$\text{Fuzzy\_cost} = [\textstyle\sum_{\text{allrules}} f_i \times \psi(f_i)] / \left[\textstyle\sum_{\text{allrules}} \psi(f_i)\right] \quad (8)$$

Where fuzzy_cost is used to specify the degree of decision making, f_i is the fuzzy all rules and variable and $\psi(f_i)$ is its membership function. The output of the fuzzy cost function is modified to crisp value as per this defuzzification method.

Forwarding node assignment based on packet category: Table 2 illustrates the forwarding node assignment. From Table 2, it reveals that for hard deadline with larger size packets, the forwarding node with high scheduling probability is assigned. Similarly, the nodes are assigned appropriately based on scheduling probability.

RESULTS AND DISCUSSION

Simulation parameters: We use NS2 to simulate our proposed Fuzzy based Mobility and Energy Aware QoS Routing (FMEAQRP) Protocol. We use the IEEE 802.11 for Wireless Hybrid Networks as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, the packet size is varied as 250, 500, 750 and 1000. The area size is 1200 m x 1200 m^2 region for 50 sec simulation time. The simulated traffic is Constant Bit Rate (CBR). Our simulation settings and parameters are summarized in Table 3.

Performance metrics: We evaluate performance of the new protocol mainly according to the following parameters. We compare the QOD (Li and Shen, 2010) protocol with our proposed FMEAQRP protocol:

- Average packet delivery ratio; it is the ratio of the number of packets received successfully and the total number of packets transmitted
- Average end-to-end delay; the end-to-end-delay is averaged over all surviving data packets from the sources to the destinations
- Throughput; the throughput is the amount of data that can be sent from the sources to the destination.
- Packet drop; it is the number of packets dropped during the data transmission

Results and analysis: The simulation results are presented in the next study.

Varying node speed: In order to evaluate the performance of both the protocols in terms of low and high mobility, the speed of the mobile nodes are varied as 2,4,6,8 and 10m/s for packet size of 250 bytes. Table 4 presents the results for varying the node speed. Figure 8-11 shows the graphical representation of the results.

Figure 8 shows the results of delay by varying the mobile speed from 1-5m/s for FMEAQRP and QOD protocols. Increase in node speed, results in increased delay as depicted by the figure. When comparing the performance of the two protocols, we infer that FMEAQRP has 40% less delay when compared to QOD, since FMEAQRP schedules the hard deadline packets through the high forwarding nodes.

Table 3: Simulation parameters

Number of nodes	10/per gate way
Number of gateways	5
Area	1200 X 1200m
MAC	IEEE 802.11b
Simulation time	50 Sec
Traffic source	CBR
Transmission rate	250Kb
Propagation	TwoRayGround
Antenna	OmniAntenna
Initial energy	4.1J
Transmission power	0.660w
Receiving power	0.395w
Packet size	250,500,750 and 1000Kb
Mobile speed	1,2,3,4 and 5m/s

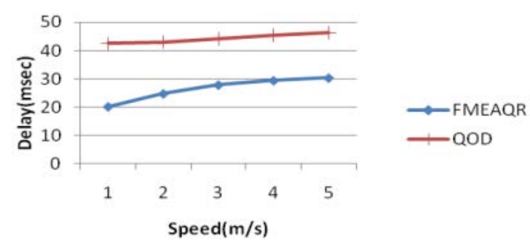

Fig. 8: Speed vs delay

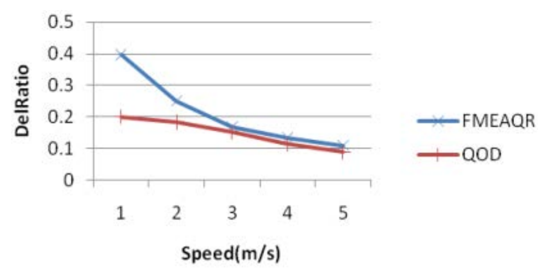

Fig. 9: Speed vs delivery ratio

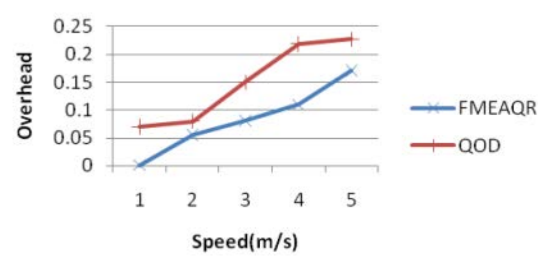

Fig. 10: Speed Vs packet drop

Figure 9 and 10 shows the results of delivery ratio and routing overhead for FMEAQRP and QOD protocols by varying the mobile speed. Increase in node speed, results in increased packet drop and decrease in delivery ratio due to disconnections. However, FMEAQRP has 24% higher delivery ratio and 14% lesser routing overhead when compared to QOD, since in FMEAQRP, forwarding nodes with better link quality and RSS are selected for scheduling.

Table 4: Results for varying the node speed

Speed(m/s)	Delay(msec)		Delivery ratio		Packet drop		Throughput(Mb/sec)	
	FME AQRP	QOD	FME AQRP	QOD	FME AQRP	QOD	FME AQRP	QOD
1	20.125	42.475	0.39710	0.20109	1320	1701	0.253	0.128
2	24.725	43.080	0.25078	0.18388	1556	1802	0.160	0.117
3	27.845	44.110	0.16962	0.1518	1815	1999	0.114	0.097
4	29.391	45.377	0.13424	0.11345	1901	2190	0.090	0.071
5	30.326	46.313	0.10959	0.08920	1911	2268	0.072	0.054

Table 5: Results for varying the packet size

PacketSize	Delay(msec)		Delivery Ratio		Packet Drop		Throughput (Mb/sec)	
	FME AQRP	QOD	FME AQRP	QOD	FME AQRP	QOD	FME AQRP	QOD
250	20.125	42.475	0.39710	0.20109	1320	2001	0.253	0.128
500	20.218	41.526	0.39812	0.23028	573	932	0.255	0.147
750	22.258	41.066	0.40836	0.24766	376	611	0.256	0.159
1000	25.456	43.213	0.41628	0.26993	273	462	0.286	0.205

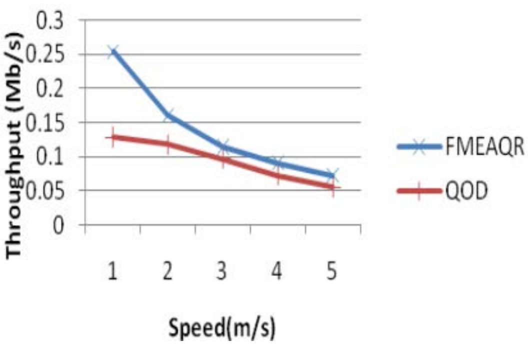

Fig. 11: Speed Vs throughput

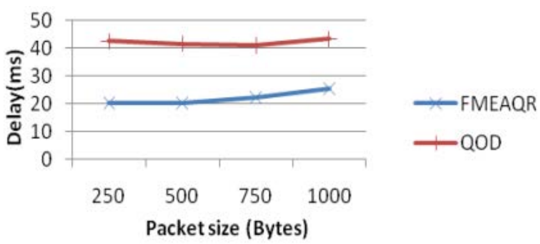

Fig. 12: Packet size vs delay

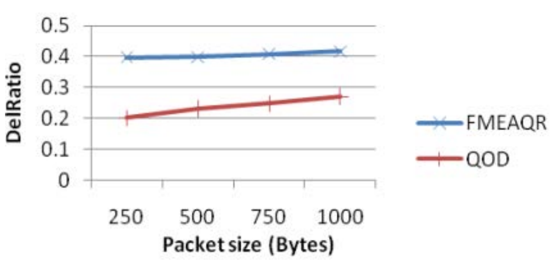

Fig. 13: Packte size vs delviery ratio

Figure 11 shows the results of throughput obtained for FMEAQRP and QOD protocols by varying the mobile speed. Increase in node speed, results in decrease in throughput due to disconnections. However, FMEAQRP

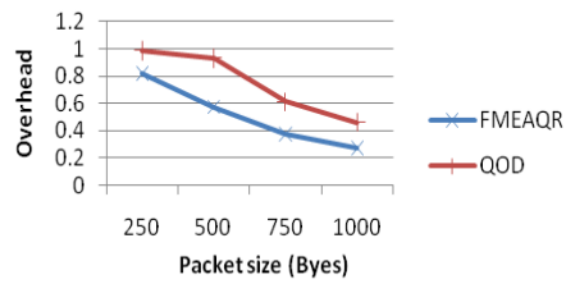

Fig. 14: Packet size vs packet drop

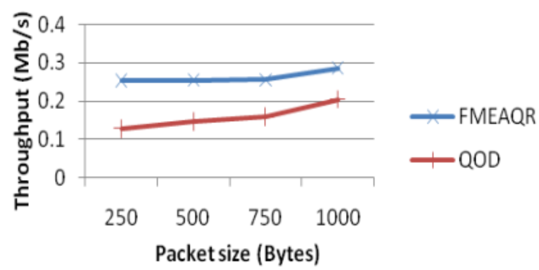

Fig. 15: Packet size vs throughput

has 27% higher throughput when compared to QOD, since FMEAQRP the forwarding nodes with better link quality and lesser load are selected for scheduling.

Varying packet size: In order to evaluate the performance of both the protocols in terms of low and high packet size, the packet size is varied as 250, 500, 750 and 1000 bytes for the node speed of 2m/s. Table 5 presents the results for varying the packet size. Figure 12-15 shows the graphical representation of the results.

Figure 12 shows the results of delay by varying the packet size from 250-1000 bytes for FMEAQRP and QOD protocols. Increase in packet size results in slightly increased delay as depicted by the figure. When comparing the performance of the two protocols, we infer that FMEAQRP has 47% lesser delay when compared to QOD, since FMEAQRP schedules the hard deadline and large sizes packets through the forwarding nodes with high probability.

Figure 13 and 14 shows the results of delivery ratio and routing overhead for FMEAQRP and QOD protocols by varying the packet size Increase in packet size, results in reduced overhead and increased delivery ratio, since the number of packets transmitted will be less. However, FMEAQRP has 41% higher delivery ratio and 37% lesser routing overheads when compared to QOD, since in FMEAQRP, forwarding nodes with better link quality and RSS are selected for scheduling.

Figure 15 shows the results of throughput obtained for FMEAQRP and QOD protocols by varying the packet size. Increase in packet size, results in increase in throughput as depicted in the figure. FMEAQRP has 37% higher throughput when compared to QOD, since FMEAQRP the forwarding nodes with better link quality and lesser load are selected for scheduling.

CONCLUSION

In this study, we have proposed a fuzzy based mobility and energy aware qos routing protocol for Hybrid Wireless Networks. In this protocol, the Link Expiration Time (LET), Residual Energy (RE) and Received Signal Strength (RSS) of a node are estimated. Then the packets are classified based on the deadline and packet size. The scheduling probability of node is estimated using fuzzy logic technique based on the parameters that includes load, space utility, RE, LET and RSS. Further, depending on the category of the packet, the corresponding forwarding node is assigned based on the estimated scheduling probability. By simulation results, we have shown that the proposed technique reduces the energy consumption and traffic load.

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