Energy Efficient Multipath Routing Protocol for Enhancing QoS and QoE in Multimedia Applications for MANETs

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Abstract: In mobile ad hoc networks (MANET) the devices are interconnected by wireless manner that are able to ubiquitously retrieve contents such as video and audio streams, still images, and scalar sensor data from the environment. MANET provides low power in hazardous environment where replacement of fault evaluation in the MANET is impossible. Hence, development of an energy efficient network is essential in MANET, where the cost of network depends on the energy consumption of each mobile node. Overutilization of energy by a mobile node cannot contribute to the utility or the network as a whole. Hence to optimize the utilization of energy at each node, we propose an energy efficient multipath routing protocol for MANET for enhancing QoS and QoE metrics (EMRP-QQ), which can eventually minimize the data loss and hence there liability of the mobile nodes and the overall network. In our proposed approach an energy efficient clustering is performed using particle swarm optimization (PSO), where all the nodes are clustered without any residual nodes left in the system. Using the appropriate selection of CH and SCH the overall networks overhead utilization is reduced and hence the QoS of the network is enhanced. The result obtained through NS-2 simulation shows that the proposed algorithm performs better than FQ-MP-OLSR approach in terms of reduced energy consumption of each node without affecting QoS and QoE metrics.

Keywords: Mobile ad hoc network (MANET), Multipath routing, Clustering, Cluster head (CH), Super cluster head (SCH), Particle swarm optimization (PSO), Quality of service (QoS), Quality of experience (QoE), Network simulator2 (NS-2).

1. Introduction

Next generation wired and wireless networks are evolving to accommodate a variety of services, including voice, data and real-time or streaming video/audio. Different applications come with diverse Quality of Service requirements, in terms of data loss, delay and throughput [1-3]. The "bottleneck" in such networks is the wireless link, not only because wireless resources (bandwidth and power) are more scarce and expensive than their wired counterparts, but also because the overall system performance degrades markedly due to multipath fading and time-dispersive effects introduced by the wireless air interface. Unlike wired network, even if large bandwidth/power is allocated to a certain wireless connection, the loss and delay requirements may not be satisfied when the channel experiences deep fades. Therefore, judicious schemes should be developed to support prioritization and resource reservation in wireless networks, in order to enable guaranteed QoS with efficient resource utilization. QoS routing is essential for providing end-to-end QoS guarantees. The Internet routing is divided into two levels hierarchically, the intra-domain routing and the inter-domain routing. Routing protocols have to be QoS-aware in both levels in order to provide end-to-end QoS support. There are many solutions for intra-domain QoS routing protocols, such as OSPF QoS Extension [4]. However, little work has been done so far to put QoS information into the context of inter-domain routing. In this paper, based on the de facto inter-domain routing standard, the Border Gateway Protocol (BGP) [5], we will discuss the mechanisms and extensions to enable QoS information advertising and routing in the inter domain level. The Internet consists of Autonomous Systems (AS). Interior Gateway Protocol (IGP) is used inside an AS, such as OSPF. BGP is essentially a hop-by-hop distance vector routing protocol for exchanging network reliability information between AS. The network reliability information, which is formatted in the UPDATE messages, can advertise or withdraw a route to a network destination. The UPDATE messages, also called advertisements, mainly contain the address of the network destinations, the paths represented in AS numbers (AS PATH), and the next hop address (NEXT HOP). Each AS calculates the degree of preference for each route it has received according to some path selection policies, installs the most preferred one into the local forwarding table, and propagates such routing decisions to neighboring AS. BGP is a policy-based routing protocol. Some BGP path selection rules from Cisco Systems are presented in [6], such as the number of hops in terms of AS, the multiple exit discriminator, etc. In general, the relationship between AS's play an important role in BGP route selection, route exporting and route importing policies. These policies reflect the business relation between different domains [7], and some of them are also essential to prevent BGP routing divergence [8] [9]. For example, the route from the customers is preferable to the routes from the peers and the providers. Recently, in order to increase network reliability, multipath routing becoming more and more practiced technique in the Internet community.

There are mainly three advantages in bringing QoS information into BGP. First, it will optimize the inter-domain packet forwarding performance. By properly using the QoS routing information in BGP messages, we can identify routes with higher available bandwidth or lower traffic load to forward data packets. Second, it will make inter-domain traffic engineering [10] more effective. Local IP traffic can be better controlled if the global Internet traffic condition is known. Third, it can provide necessary information for other inter-domain related protocols which need QoS support from the routing layer. For example, in the inter-domain resource reservation protocol i.e. border gateway reservation protocol (BGRP) [11], the block rate will be decreased if the signal messages are distributed according to appropriate QoS metrics. However, there are two major difficulties when QoS information advertising is introduced into BGP. First, the

extension has to be scalable. BGP is originally designed to exchange pure reliability information. If QoS metrics are added, the scalability of Internet routing should not be compromised by the dynamic nature of the QoS information. Second, the QoS representation should be able to handle the heterogeneity of links or routes in the inter-domain routing.
The connections between BGP routers may be of different types. For example, some connections may use direct physical links, while some may use the paths provided by the intra-domain routing, i.e., IGP routes. Moreover, the route refreshing periods may vary in different domains. Thus, the QoS information obtained from different AS's has different degrees of precision. In order to cope with the two difficulties described above, QoS metrics have to be appropriately selected. As we know, there exist two types of QoS metrics: the static QoS metrics and the dynamic ones. The static metrics are deterministic all the time, such as the link capacity and AS hop count. The dynamic metrics vary according to different traffic loads, such as the available bandwidth of a link or a path. Routing using static metrics has low message overhead. After the routing table is set up, QoS information of routes will not be further exchanged, because the values of the static QoS metrics are constant. However, static QoS metrics usually can not reflect the instantaneous network status. For example, even if the link capacity is high, the real available bandwidth could be low due to high traffic load. On the other hand, dynamic QoS metrics can represent the instantaneous network status, but high routing message overhead is incurred due to the fluctuation of dynamic QoS metrics over time. Routing based on the instantaneous QoS metrics without any control is not scalable in the global Internet. Some simple statistics based on the instantaneous values, such as average available bandwidth, can reduce the message overhead, but they are too coarse-grained to model the instantaneous information well.
In this paper, we propose energy efficient multipath routing protocol for MANETs without affecting QoS and QoE metrics (EMRP-QQ). In multipath routing energy efficiency is achieved by clustering techniques.
The remainder of the paper is organized as follows. Section 2 presents the recent works related to our contributions. The problem formation and solution with the system model is describes in Section 3. We propose energy efficient routing protocol details and its mathematical formulation in Section 4. The performance of proposed protocol is present in section 5. Finally, the paper concludes in Section 6.

2. Related works

Chaudhari *et al.* [12] have proposed central authority based resource prediction mechanism considering mobility (CA-RPM) that predicts the resources using agents through the resource prediction agency consisting of one static agent, one cognitive agent and two mobile agents. Agents predict the traffic, mobility, buffer space, energy, and bandwidth effectively that is necessary for efficient resource allocation to support real-time and multimedia communications. The mobile agents collect and distribute network traffic statistics over MANET whereas a static agent collects the local statistics. CA creates static/mobile agent during the process of resource prediction. Initially, the designed time series wavelet neural networks (WNNs) predict traffic and mobility. Buffer space, energy, and bandwidth prediction use the predicted mobility and traffic.
Santiago Gonzalez *et al.* [13] have evaluated the scalable video streaming over mobile ad hoc network by two schemes. In the first scheme, video is transmitted by means of maintaining a constant transmission rate and sending the information of all layers. The other scheme incorporates an adaptive model in which the source of traffic eliminates layers from SVC stream in order to adapt to the available bandwidth. Two complementary tools for the study of SVC traffic over data networks. The routing protocol with inter layer communication used to estimate and inform the source resources available on the network (in terms of available bandwidth).
Lyes Khoukhi *et al.* [14] have explored an integrated new intelligent cross-layer QoS solution based on fuzzy logic for wireless mobile ad hoc networks. This choice is justified by the fact that fuzzy logic is well adapted to systems characterized by imprecise states, as in the case of ad hoc networks. Fuzzy QoS, used to improve the control of traffic regulation rate and congestion control of multimedia applications. Fuzzy QoS integrates three mechanisms at different layers: a fuzzy logic approach for best-effort traffic regulation (FuzzyQoS-1), QoS decision making for traffic regulation (FuzzyQoS-2), and a fuzzy logic approach for threshold buffer management (FuzzyQoS-3). The delay feedback information received from the network is the key parameter used in FuzzyQoS-1 and FuzzyQoS-2, to ensure that best-effort traffic coexists well with real-time traffic in the multimedia applications. The feedback measurement represents the packet delay measured by the IEEE 802.11 MAC which is integrated as a part of the Fuzzy QoS architecture.
Stefania Colonnese *et al.* [15] have proposed sender-assisted HTTP streaming strategy that avoids unnecessary dynamic rate adaptation using an efficient scheduling of the HTTP-GET request underlying the streaming session. Specifically, the sender proactively foresees upcoming underflow events using information on the encoded video content available at the sender side, and it uses this information to adaptively control the duration of intervals between consecutive video segment request performed by the client. The strategy enables efficient and flexible management of the rapidly varying random fluctuations of the packet delay that are caused by the interplay of the characteristics of the encoded content and of the network conditions.
Jun-Li Kuo *et al.* [16] have presented cross layer approach for P2P live streaming tailored to MANET, called COME-P2P (Cross layer Overlay for Multimedia Environment on wireless ad hoc P2P). It motivate live streaming for high data rate and time sensitivity on P2P-MANET for scalability, extensibility, and persistency. The COME-P2P used to achieve the high smoothness for live streaming, to shorten the routing propagation delay, and to reduce the signaling overhead. Scheme consists of three algorithms, first algorithm maintains the application layer overlay which is proximal to physical layer topology; the second algorithm provides an efficient routing via IPv6 to achieve the high data rate; and the last algorithm handles the interaction of cross layer messages to keep an optimized shortest routing path. The integration of P2P overlay and MANET routing can update the cross-layer information to reduce signaling

overhead (control overhead), speed up recovery time, and improve streaming stability.

Chhagan Lal *et al.* [17] address aforementioned limitations of the existing QoS-aware routing, and the multi constraint QoE centric routing technique for efficient transmission of multimedia traffic in MANETs. In large scale emulation setup, human-in-loop and hardware-in-loop QoE evaluation and real-time video transmission using multimedia software's with reactive MANET routing protocol. The weighted metric based link quality estimation method considers the effects of shadowing and network mobility during its QoE-centric route discovery process. A bi-objective mathematical model is introduced to calculate the joint route-quality and route-delay over candidate routes. A test bed used to testing and evaluating the performance of real-time video streaming (generated and captured by physical machines).

Ying Bao *et al.* [18] have presented, to improve the quality of experience (QoE) in terms of network media transmission service, and QoE evaluation basis for adjusting the transmission control mechanism. Therefore, a kind of QoE collaborative evaluation method based on fuzzy clustering heuristic algorithm is used, which is concentrated on service score calculation at the server side. The server side collects network transmission quality of service (QoS) parameter, node location data, and user expectation value from client feedback information. Then it manages the historical data in database through the "big data" process mode, and predicts user score according to heuristic rules. On this basis, it completes fuzzy clustering analysis, and generates service QoE score and management message, which will be finally fed back to clients.

Shivashankar *et al.* [19] have proposed an efficient algorithm for MANETs, which maximizes the network lifetime by minimizing the power consumption while establishing path with the help of modified DSR. The proposed work minimizes the energy consumption per packet and maximizes the network lifetime. The design objective of modifying DSR is to select energy efficient paths.

Jamali *et al.* [20] have proposed routing protocols called BPSO-TORA which offers high degree of scalability. Binary Particle Swarm Optimization algorithm (BPSO) is used to improve the energy awareness feature to the TORA routing protocol. The protocol considers route length in its route selection process and also includes routes energy level in its calculations. It formulates the routing issue as an optimization problem and then employs BPSO to choose a route that maximizes a weighted function of the route length and the route energy level.

Ravi *et al.* [21] have proposed energy aware span routing protocol (EASRP) that uses energy-saving approaches such as span and adaptive fidelity energy conservation algorithm (AFECA). Energy consumption is further optimized by using a hardware circuit called the remote activated switch (RAS) to wake up sleeping nodes. These energy-saving approaches are well-established in reactive protocols.

Basurra *et al.* [22] have discussed zone based routing with parallel collision guided broadcasting protocol (ZCG) that uses parallel and distributed broadcasting technique for reducing redundant broadcasting and to accelerate the path discovery process, while maintaining a high reach ability ratio as well as keeping node energy consumption low. ZCG uses a one hop clustering algorithm that splits the network into zones led by reliable leaders that are mostly static and have plentiful battery resources.

Chettibi *et al.* [23] have proposed dynamic fuzzy energy state based AODV (DFES-AODV) routing protocol for MANETs. In DFES-AODV route discovery phase, each node uses a Mamdani fuzzy logic system (FLS) to decide its route requests (RREQs) forwarding probability. The FLS inputs are residual battery level and energy drain rate of mobile node.

3. Problem solution and System model

In this section, we first describe the problem of routing protocol in Boushaba *et al.* [19] and propose solution for that problem. We then describe the system model for proposed solution.

3.1 Problem Identification and solution

The instability and limited resources in mobile ad hoc networks (MANETs) make the video transmission over such networks a challenging task. Transmission of video streams through multipath routing protocol in MANETs can enhance the quality of video transmission. In [24], authors proposed extension of MP-OLSR (multipath optimized link state routing protocol) [25] [26], named FQ-MP-OLSR (fuzzy based quality of service MP-OLSR), which integrates two fuzzy systems.

1. The first receives as inputs three quality of service (QoS) links metrics: delay, throughput and signal to interference plus noise ratio (SINR) and returns as output multi constrained QoS metric used to find the best paths.
2. Then the fuzzy system is applied to adapt cost functions used to penalize paths previously computed by Dijkstra's algorithm.

To schedule multimedia traffic among heterogeneous multiple paths, FQ-MP-OLSR integrates also the weighted round-robin (WRR) scheduling algorithm, where the path weights, needed for scheduling, are computed using the multi-constrained QoS metric provided by the first fuzzy system. These mechanisms allow FQ-MP-OLSR to improve video QoS and QoE, against the MP-OLSR that uses classical mechanisms such as hop count as single routing metric, cost functions without adaptation and round-robin (RR) as scheduling algorithm. The research in MANETs with the QoS routing focused on energy consumption. In the establishment of a network in the linked hierarchy, the clustering mechanism forms an efficient topology control methodology which stabilizes the traffic load and improves the overall performance and also increases the lifetime of MANETs. FQ-MP-OLSR approach is not fulfilled our quality routing requirement, because the following limitations are involved. They consider only three QoS links metrics: delay, throughput and signal to interference plus noise ratio (SINR). The QoS define cost functions only, and it is calculated from the Fuzzy rules and sets. The old multipath Dijkstra's algorithm with some modifications like "without eliminating nodes or links" used to compute the paths. Finally, the authors only focus on the some traditional link metrics such as, packets loss ratio, delay, jitter and routing cost.

A node wants to send information to another node; it has to select an optimal path such that the obtained QoS should be optimal. The QoS of the received information mainly depends on the available energy, bandwidth, stability of established path and the time delay of the respective path. In this paper, we propose an energy efficient multi path routing protocols, which the main contributions are follows.

1 An efficient clustering is performed using PSO [27], where all the nodes are clustered without any residual nodes left in the system.
2 Using the appropriate selection of cluster head (CH) and super cluster head (SCH) [28] the overall networks overhead utilization and energy consumption is reduced and hence the lifetime of the network is enhanced.
3 The nature of traffic also plays an important role in establishing an optimal path between source node and destination node. Generally, the traffic is categorized as real time traffic and non-real time traffic. Real time traffic (multimedia information) having more data. So, multipath routing is preferable for real time traffic to reduce the time delay improve throughput with reducing energy consumption. The performance of the proposed routing approach validated by using both real time (videos) and non real time (constant bit rate) test vectors.(CBR is not considered in our paper) The proposed EMRP-QQ routing protocols compared with FQ-MP-OLSR routing protocols considering parameters which include packet loss ratio, energy consumption, routing cost, mobility, delay, and throughput. Then QoE is validated by peak signal to noise ratio (PSNR), structural similarity (SSIM) and video quality metric (VQM) of proposed routing approach is compared with the FQ-MP-OLSR routing protocols.

3.2 System model

The system model for our proposed network model is shown in Figure 1. The network consists of base station (BS), mobile nodes (MNs), cluster head nodes (CHs) and super cluster head nodes (SCHs). BS employed to collect the information from the mobile nodes. During an event if interest (such as flooding, earthquake...etc) the mobile nodes deployed unevenly and with mobility must send the data efficiently to its BS with high efficiency and reliability. The every clusters have a CH node, which collect all the information from other nodes in own cluster. The CHs are only eligible to directly communicate with the neighboring CHs node. Then the collective CHs are together to select the best node i.e. SCH from among the CH such that only SCH is eligible to directly communicate with the base station.

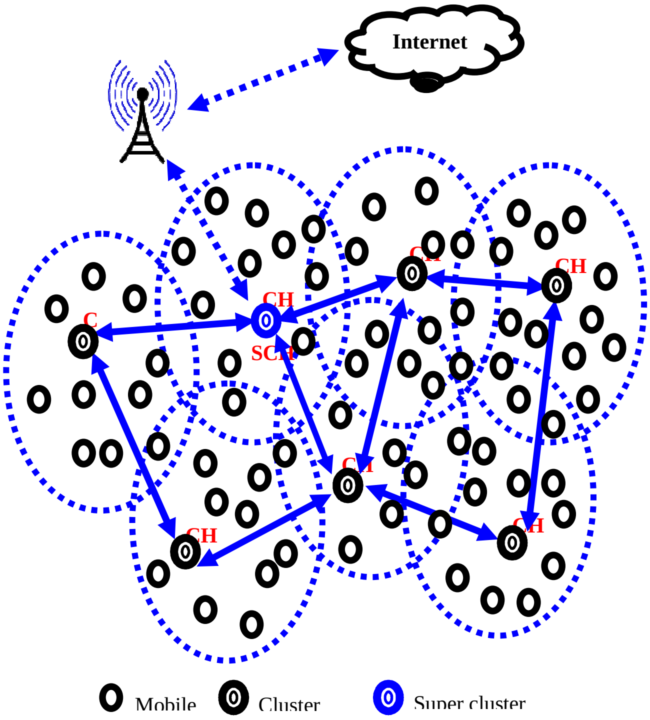


Figure 1. System model for our proposed work

4. Proposed routing protocol

The proposed routing protocol consist of three stages such as cluster formation, cluster head selection (CH) and super cluster selection (SCH) and the process steps are briefly described in the following sub sections.

4.1 Cluster formation using PSO algorithm

In the proposed protocol Particle Swarm Optimization (PSO) is employed for efficient clustering of nodes with least redundant (un-clustered) node in the network. It is a random optimization technique based on population and computational technique that optimizes a problem (situation) using series of iterations to enhance the possible solution for a given quality measure A solution to the problem of complex non-linear optimization has been proposed using PSO by means of imitating the bird flocks behavior. PSO simulates the behavior of flocking birds, where a group of birds randomly search food in a given area.

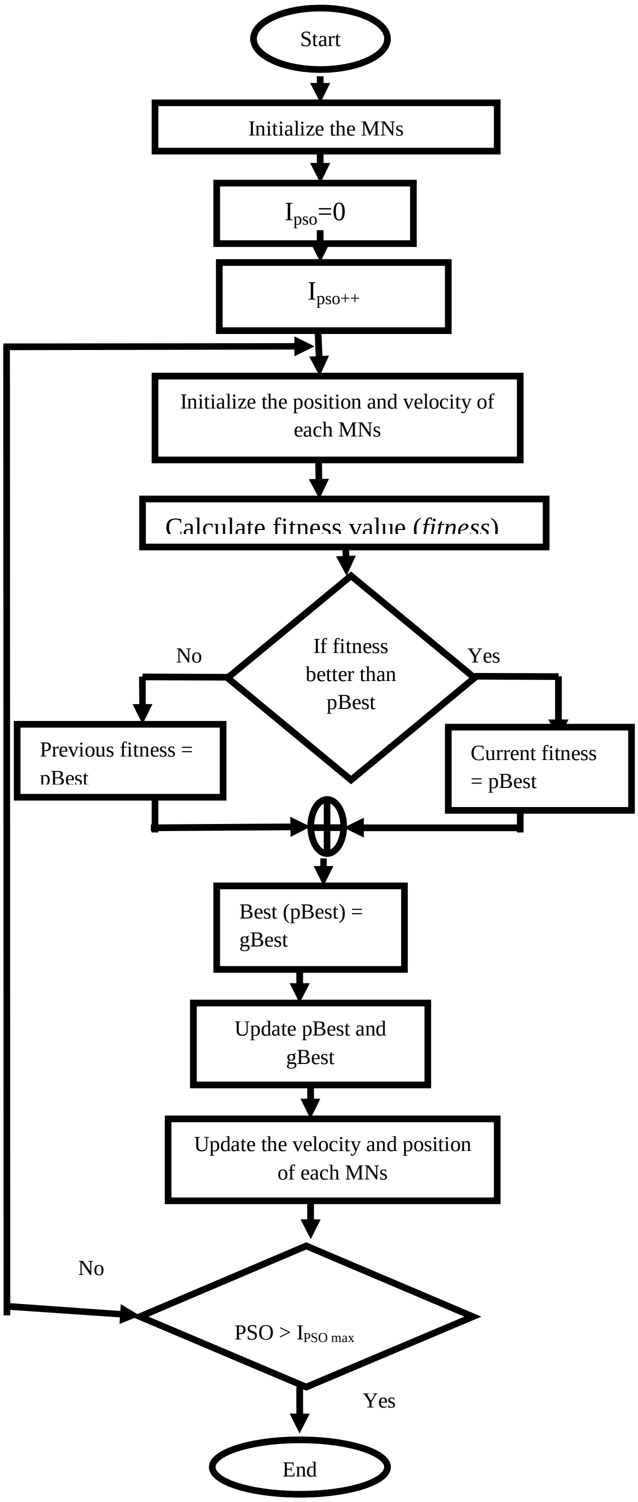


Figure 2. PSO algorithm for cluster formation phase

Consider there is only one piece of food in the area of search and no birds know that where the food is. But they know how far the food is in each iteration. Hence, the best strategy is to follow the bird which is nearest to the food. PSO similarly utilizes the strategy where each "bird" represents the solution in the given environment (for the proposed environment) i.e. "particle". Particles are considered using the two parameters position and velocity. Each particle have velocity and position values, which represent the direction of their flying. In each iteration, velocity of each particle is updated using the current velocity and the previous *local_best* and *global_best* position. Based on that *new_velocity* and *new_position* values are updated. The first best maximum value is known as the *pBest* .Then the second best value is evaluated keeping the best value so far obtained in the whole swarm population as the *gBest* (global best).

The working flow of PSO algorithm during cluster formation is shown in Figure 2, some of the nodes which were left out without being a member of any cluster which results in residual node formation, clustering is carried out until all the nodes become a member of any of the present clusters. Initially, when all the nodes are deployed in the network, the base station broadcasts an *INITIATE_MSG* followed by an *INFO_COLLECT message* from all the mobile nodes in network.

The hello and information collective message format is shown in Figure 3 and 4 respectively. The nodes after receiving *INITIATE_MSG* and the *INFO_COLLECT message* from the base station starts to communicate with every other node in the given region, by broadcasting an *HELLO_message*, in their cluster region.

Hello Message			
Node's ID	Residual energy	Band width	Connectivity

Figure 3. Hello Message format

After the broadcast of the HELLO_*messge*, every mobile node sends an *INFO_COLLECT reply message* to the base station. *HELLO_message* contains information about the nodes id and its residual energy, bandwidth and connectivity. *INFO_COLLECT reply message* sent from the *n*th node to the base station contains the information such as (1) position (u_n,w_n) of the node (2) velocity (v_{1n}, v_{2n}) of the nodes. (where v_{1n} is the current velocity of node n, v_2 is the average velocity of node n) and (3) Energy (E_n) of the *n*th node. Hence for each node the value of position, velocity and energy are maintained and updated at the base station.

INFO_COLLECT Message			
Node's ID	Position (u,w)	Velocity (v_1, v_2)	Energy (E)

Figure 4. INFO_COLLECT message format

In this proposed algorithm, each node is considered as the particle. Here the base station make the nodes to perform cluster formation, which is carried out using PSO. Using PSO, the fitness of each particle is calculated to choose the cluster particles (cluster member selection). Fitness value in our proposed approach depends on:

- The energy of the node (particle) E_m.
- Connectivity (C_{mn})
- Distance of node/particle (n) within the radio range 'a' from node m
- Energy of the node/particle (n) within the radio range 'a' from node m

Based on the fitness value clustering is carried out considering the entire network and hence eliminating the presence of residual nodes in the network. The nodes with maximum number of connectivity and residual energy are considered as the cluster particle (member).

Fitness value =

$$\left(\ \kappa_1 * (\frac{D_{nm}}{C_{mn}})\ \right) + \left(\ \kappa_2 * (\frac{E_{Avg_{c_{mn}}}}{E_m})\ \right) + \left(\ \kappa_3 * (\frac{1}{C_{mn}})\ \right) \quad (1)$$

Where, $D_{nm} = \sqrt{(u_m - u_n)^2 + (w_m - w_n)^2}$ i.e. the distance between node m and nth node $n = \{1,2,3.....l\}$ be the number of nodes (particles) reachable by the node in the given sample space $0 < \kappa_1 < 1$, $0 < \kappa_2 < 1$ and $\kappa_3 = 1 - \kappa_1 - \kappa_2$.

Fitness value of each node is calculated during every iteration and the maximum fitness value obtained is taken as the *local_best*. The maximum value among all the fitness values obtained is taken as *global_best*. Position and velocity updation is carried out in PSO for every particle as follows:

V_update $_p$=W$_{velocity\ p}$+
W$_1$ (Pervious position of node p-current position of node p)+
W$_2$ (precious position of node p current position of node p)*
(2)

P_update$_p$=Previous position of node p +V_update$_p$ (3)

Where, $W_{velocity\ p}$ =weight of nodes velocity, W_1 and W_2= weight of nodes location.

As shown in Figure 5, *(X, Y)* is the assumed workspace and '*a*' is the coverage of each nodes. The total number of clusters formed in the considered area can be calculated as:

$$N = \frac{total\ network\ area}{individual\ cluster\ area} = \frac{(X*Y)}{(x*y)} \quad (4)$$

Where, *(x, y)* be the coordinates of the cluster in the region, *(X, Y)* be the coordinates of the sensing region

From the Figure 5, using Pythagoras theorem the value of 'a' can be written as:

$$a = \sqrt{\frac{x^2}{4} + \frac{y^2}{4}} \quad (5)$$

Let us assume, *x*= *y* = *u* and *X*=*Y*. Equation (4) and (5) becomes:

$$a = \frac{u}{\sqrt{2}} \quad (6)$$

$$N = \frac{(X*Y)}{u^2} = \frac{(X*Y)}{2a^2} \quad (7)$$

The upper bound of the number of clusters formed in a network can be:

$$N = \left\{ (\frac{X*Y}{x*y}) + (\frac{X}{x}) + (\frac{Y}{y}) \right\} \quad (8)$$

Substituting, *x*= *y* = *u* and *X*=*Y* in Equation (5)

$$N = \frac{(X^2) + (2\sqrt{2} * x*a))}{2a^2} \quad (9)$$

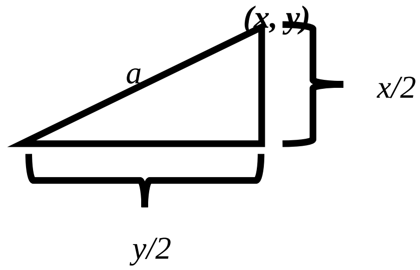


Figure 5. Pythagoras theorem

4.2 Cluster Head Selection

The modified energy efficient CH selection technique based on parameters like residual energy, distance to the neighbor, density, maximum distance and angle .The core aim of this technique is to minimize the heavy data traffic and high energy consumption in the network. The development technique fixes each CH near to the base station event while the remaining set of the CHs are appointed in the middle of each cluster to achieve the highest level of energy efficiency.

- **Residual energy (*RE$_n$*)**: A cluster head should have enough energy to perform packet transmission, Witness data flow and process the data. *CH$_{RE}$>Threshold*
- **Maximum distance**: is the maximum distance between node *m* and node *n* i.e. D_{nm}
- **Angle**: Angle of the node *m* to its neighboring node *n*
- **Density (ρ)**: Density (ρ) represents the number of nodes (mobile nodes/particles) in a given region. ρ =1 for thick region ρ =2 for thin region
- **Distance to the Neighbor** (D_{nm}): A CH must have smallest transmission distance to all its member nodes in the given densely deployed cluster. Hence, the CH must efficiently cover the given region with least amount of energy consumption.

Active nodes in a region '*a*' around a node to select itself as the CH can be calculated using:

Active *nodes* =

$$\frac{RE_n}{\left(\sum_{i=1}^{n} D_{nm} / D_{nm(\max)}\right)^2 + \left(\rho - \left(\frac{D_i}{100}\right)\right)^2} \ \forall\ nodes \quad (10)$$

4.3 SCH Selection using Fuzzy logic

Mobile nodes send the data in a given environment after detecting an event (interference). CH collects the information and aggregates the data before sending it to the bases station. As the CH consumers more energy in broadcasting the message the lifetime of CH decreases and hence leads to a reduction in the usefulness of the cluster (which contains the CH with low residual energy). Hence to increase the lifetime of the cluster and to increase the lifetime of the cluster head, we propose to elect a super cluster head (SCH) in the considered region. These Super Cluster Head are selected among the selected CH and can directly send the data directly to the BS using fuzzy interference engine (Mamdani's rule) by choosing fuzzy descriptors such as remaining battery power, the BS, the centrality of the cluster, and energy dissipation ratio. As only SCH can directly send the data to the BS, bandwidth utilization is effective. Here instead of utilization of multiple CHs, only a single SCH is utilized, this can hence enhance the energy efficiency and reduce the energy consumption, to account to increase in the overall lifetime of the network.

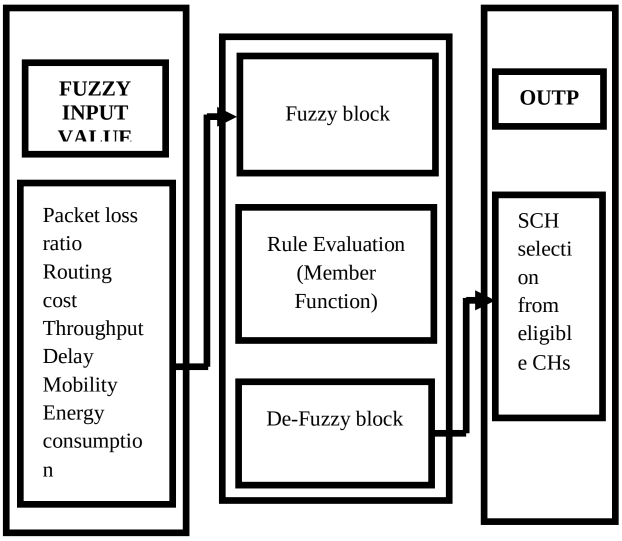


Figure 6. Fuzzy Interference system for SCH selection process

The Mamdani's fuzzy model consists of four steps and the working functions are described in Figure 6. The four steps are as follows:

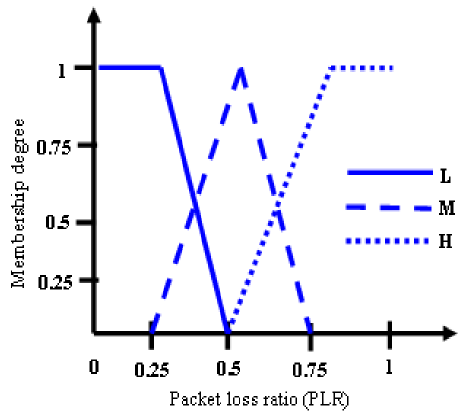
1. Fuzzification- In fuzzification, inputs are given with crisp value and changed into fuzzy sets.
2. Rule Evaluation- The fuzzified inputs are taken and applied to the antecedents of the Fuzzy rules. It is then applied to the consequent membership function.
3. Aggregation of the rule outputs- This involves the merging of the output of all rules.
4. Defuzzification- Defuzzifier transforms the fuzzy set into a crisp value.

The linguistic variables for the fuzzy set are set low, medium and high. Both trapezoidal and triangular membership functions are employed for low, high and medium variables respectively. The fuzzy rules are driven by fuzzy input sets such as packet loss ratio (PLR), routing cost (RC), link throughput (T), link delay (D), mobile node mobility (M) and energy consumption (E) and the relation as follows:

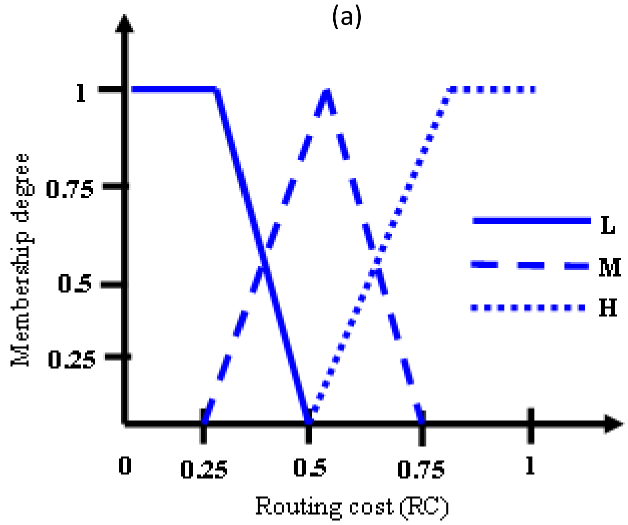
$$SCH_{eligibility} = PLR + RC + T + D + M + E \quad (11)$$

Where $SCH_{eligibility}$ is the SCH eligibility factor. Since during each information exchange, a node consumes energy, remaining battery power of a node decreases. Whereas all fuzzy inputs are considered to be an additive factor, since the distance of SCH from the BS increases or decreases as the CH moves.

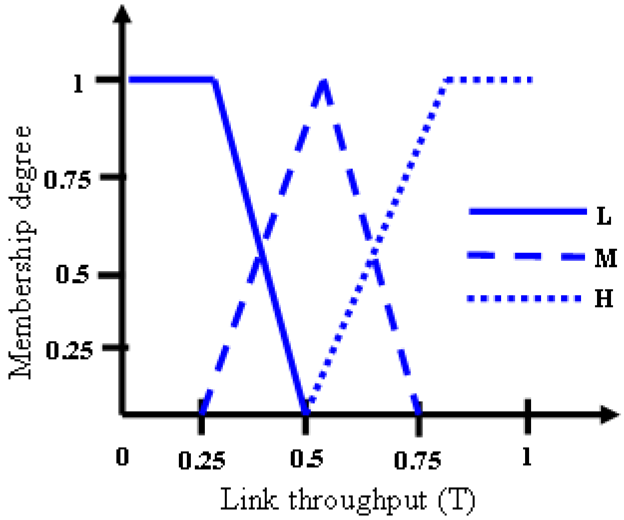
The membership function is used to define the crisp input into fuzzy inputs. In our case, the crisp inputs are PLR, RC, T, D, M and E are described by the fuzzy inputs in terms of three levels such as low (L), medium (M) and high (H). The membership functions of all inputs are described in Figure 7 a-f respectively. Centrality value depicts the connectivity of the CH with respect to other CHs in the given region. $SCH_{eligibility}$ value of a node depicts the chances of a node being an SCH in the given network. The output of $SCH_{eligibility}$ is composed of three membership functions such as low (L), medium (M) and high (H) is shown in Figure 7g.



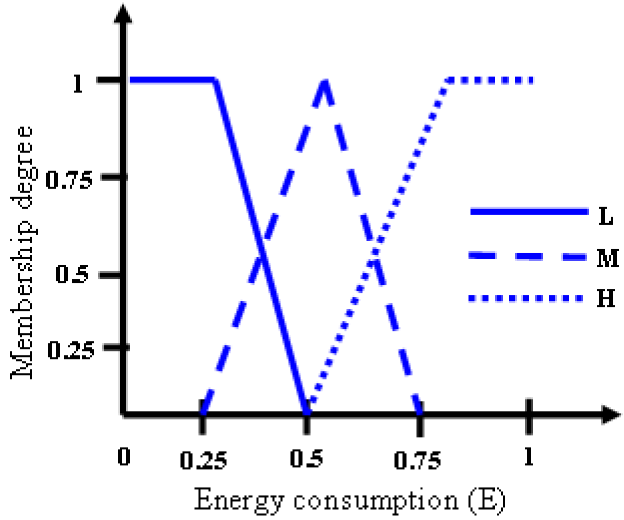
(a)



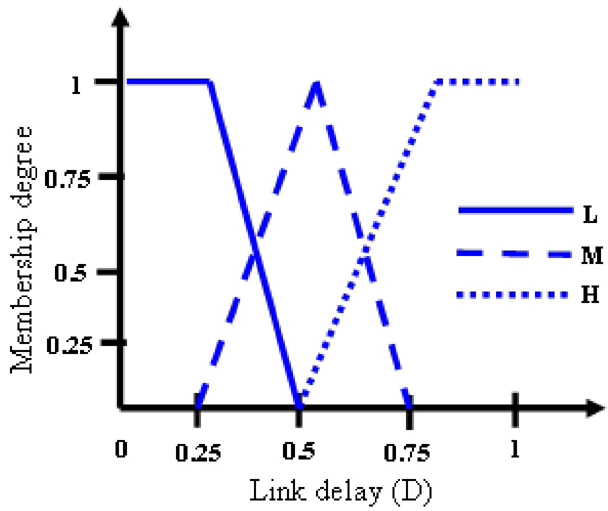
(b)



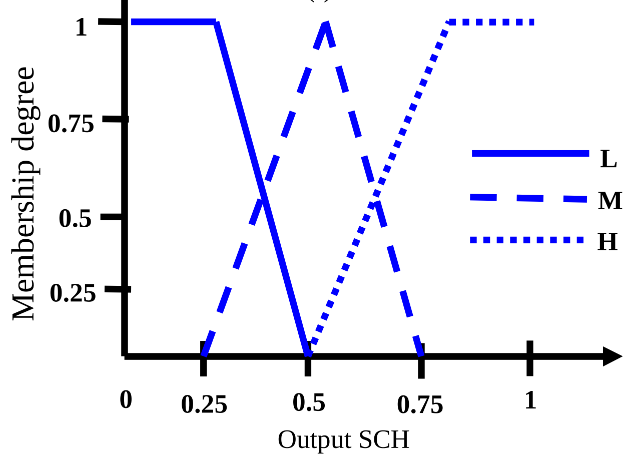
(c)



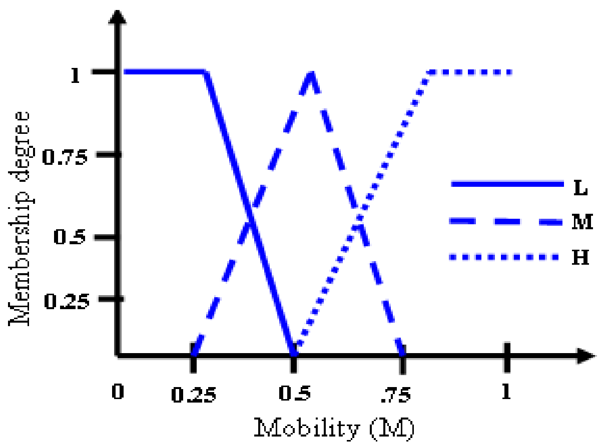
(f)



(d)



(g)



(e)

Figure 7. Membership function for (a) Packet loss ratio (PLR) (b) Routing cost (RC) (c) Link throughput (T) (d) Link delay(D) (e) Node mobility (M) (f) Energy consumption (g) Output SCH

A CH has a high chance of being an SCH only if the conditions in Table 1, from among multiple conditions are satisfied. Hence, using this fuzzy logic the best CH is selected as the SCH, with a reduction in utilization of network overhead and minimal power consumption. This leads to reduce the data loss and route cost, which in turn enhance the throughput, delay of the MANETs, where nodes are provided with minimal battery power.

No	**PLR**	**RC**	**T**	**D**	**M**	**E**	**Output SCH**	**No**	**PLR**	**RC**	**T**	**D**	**M**	**E**	**Output SCH**
1	L	L	L	L	L	L	M	248	M	L	L	L	M	M	M
2	L	L	L	L	L	M	M	249	M	L	L	L	M	H	M
3	L	L	L	L	L	H	M	.							
4	L	L	L	L	M	L	M	**393**	**M**	**L**	**H**	**L**	**L**	**L**	**H**
5	L	L	L	L	M	M	M	.							
6	L	L	L	L	M	H	M	486	M	H	H	H	H	H	L
.	.	.	.	.	.	.	.	487	H	L	L	L	L	L	M
192	**L**	**L**	**H**	**L**	**L**	**L**	**H**	488	H	L	L	L	L	M	M
.	.	.	.	.	.	.	.	.							
243	L	H	H	H	H	H	L	**675**	**H**	**L**	**H**	**L**	**L**	**L**	**H**
244	M	L	L	L	L	L	M	.							
245	M	L	L	L	L	M	M	727	H	H	H	H	H	L	L
246	M	L	L	L	L	H	M	728	H	H	H	H	H	M	L
247	M	L	L	L	M	L	M	729	H	H	H	H	H	H	L

Table 1: Fuzzy Rule for selection of SCH from multiple CHs

5. Simulation results

The Network Simulator (NS2) is used to simulate the proposed routing protocol EMRP-QQ. The performance of routing protocol is analyzed by three different test scenarios such as energy consumption, QoS metric analysis and QoE metric analysis. Energy consumption of proposed routing protocol EMRP-QQ is compared with the previous energy aware routing protocols described in section 2 such as EDSR [19], BPSO-TORA [20], AFECA [21], ZCG [22], and DFES-AODV [23]. Then the quality analysis of proposed routing protocol EMRP-QQ is compared with the previous QoS and QoE aware routing protocol FQ-MP-OLSR [24]. We want to know how our protocol reacts at different mobility cases by varying node speed. We set up the simulation in an area of 1000 square meters for a random waypoint mobile model with varying number of nodes and IEEE 802.11 MAC protocol is used for our implementation. The two ray ground transmission model is used with the transmission range 250m and 11 Mbps bandwidth. The test scenario for proposed routing protocol is described in Table 2.

Table 2. Test scenarios

Scenario	Number of nodes	Node speed	Multimedia data
1	100-500	10 m/s	Low (352×288) and high (1080×720) quality
2	100	10-50 m/s	Low (352×288) quality video
3	100	10-50 m/s	Low (352×288) and high (1080×720) quality

Evalvid tool [29-30] is used to convert the multimedia data (audio/video) frames in to NS2 input source file, which handles the information of multimedia data (audio/video) frames. The converted source file then converted in to MPEG-4 codec format and forward to destination from source. The multimedia source file *akiyo_cif.yuv* with 300 frames in 352×288 low quality and 1080×720 high quality format is used for performance analysis.

5.1 Energy consumption comparison

It is the amount of energy consumed by the source or intermediate nodes to transmit the data packets/frames to the receiver. It is analyzed by varying the number of nodes, constant node speed with the video quality of 352×288 (low) and 1080×720 (high) and simulated result plot is shown in Figure 8. The plot clearly depicts the energy consumption of proposed routing protocol EMRP-QQ is very low compare to EDSR [19], BPSO-TORA [20], AFECA [21], ZCG [22], and DFES-AODV [23].

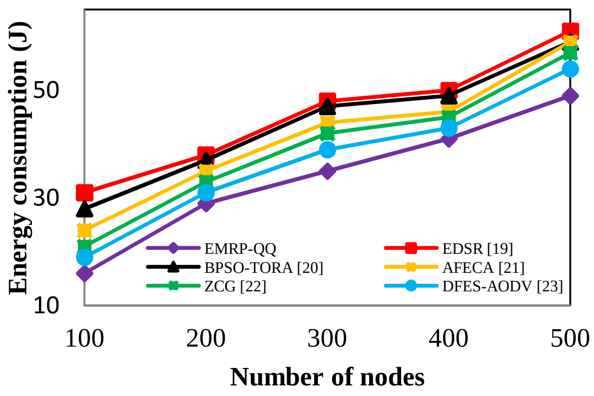


Figure 8. (a) Low quality video source file

5.2 QoS metric analysis

In this subsection the QoS metrics of proposed routing protocol is analyzed by the multimedia data stream is transferred from the source to destination, the constant bit rate (CBR) is used as background traffic sources. The multimedia source file *akiyo_cif.yuv* with 300 frames in 352×288 low quality and 1080×720 high quality format is used for performance analysis. The proposed routing protocol used to avoid the multimedia source loss in hybrid network, the quality of multimedia sources in EMRP-QQ and FQ-MP-OLSR is analyzed by different QoS metrics such as packet loss ratio, routing cost, throughput, delay and energy consumption.

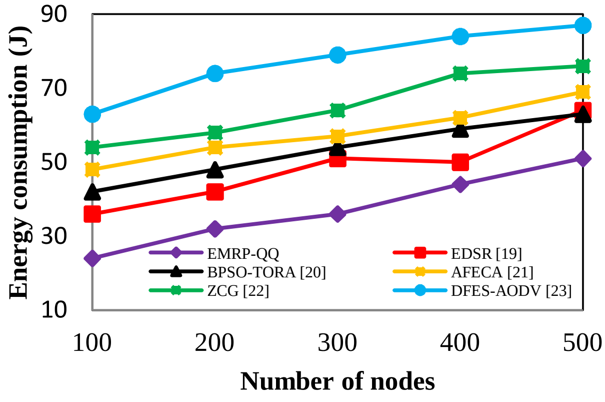


Figure 8 (b) High quality video source file

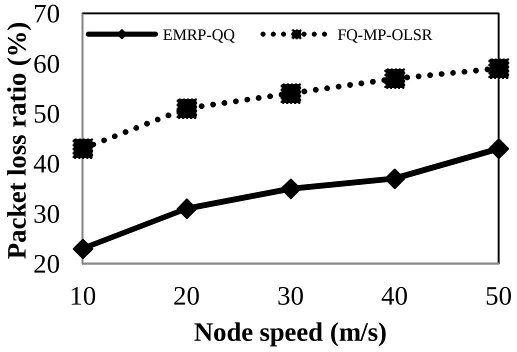
Packet (multimedia source) loss ratio is the ratio between number of dropped multimedia data packets/frames in destination and total data packets/frames sent from source. It is analyzed by varying node speed with constant node is shown in figure 9a. The plot clearly depicts the packet loss ratio of proposed protocol EMRP-QQ is very low compare to FQ-MP-OLSR routing protocol.

Routing cost is number of hops between source to destination. It is analyzed by varying the speed of node with constant node is shown in figure 9b. The plot clearly depicts the routing cost of proposed routing protocol EMRP-QQ is very low compare to FQ-MP-OLSR routing protocol.

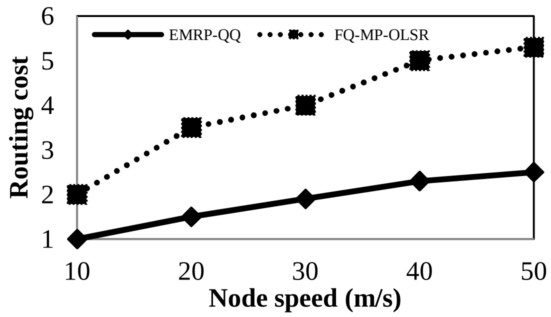
Throughput is the rate of successful message delivery over routing path. It is usually measured in bits per second (or data packets per second or data packets per time slot).It is analyzed by varying the node speed with constant node is shown in figure 9c. The plot clearly depicts the throughput is very high in proposed routing protocol EMRP-QQ compare to FQ-MP-OLSR.

End to end delay is the amount of time taken to transmit the multimedia data packets/frames from the source node to the destination in the given network. It is analyzed by varying the node speed with constant node is shown in figure 9d. The plot clearly depicts the end to end delay of proposed routing protocol EMRP-QQ is very low compare to FQ-MP-OLSR routing protocol.

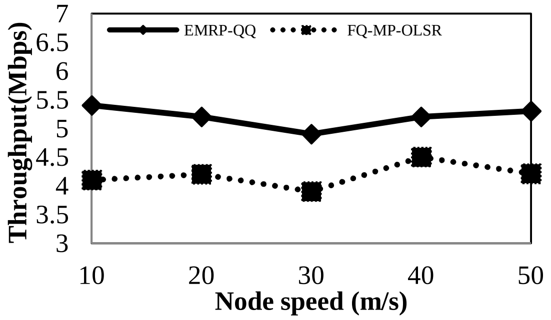
Energy consumption is the amount of energy consumed by the source or intermediate nodes to transmit the data packets/frames to the receiver. It is analyzed by varying the node speed with constant node is shown in figure 9e. The plot clearly depicts the energy consumption of proposed routing protocol EMRP-QQ is very low compare to FQ-MP-OLSR routing protocol.



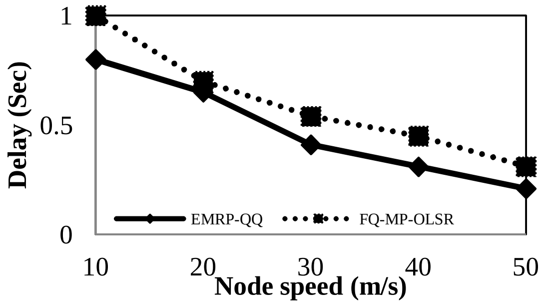
(a)



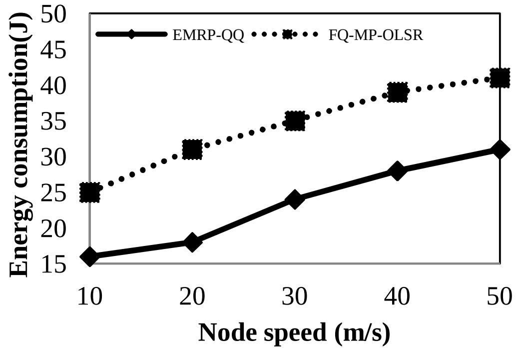
(b)



(c)



(d)



(e)

Figure 9 Quality analysis (a) Packet loss ratio (%) (b) Routing cost (c) Throughput (Mbps) (d) Delay (Sec) (e) Energy consumption (J)

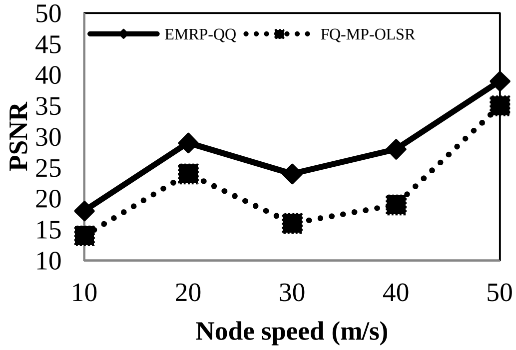
5.3 QoE metric analysis

In this sub section to analyze the QoE metrics of multimedia data packets/streams by using three metrics such as peak signal to noise ratio (PSNR), structural similarity (SSIM) and video quality metrics (VQM).

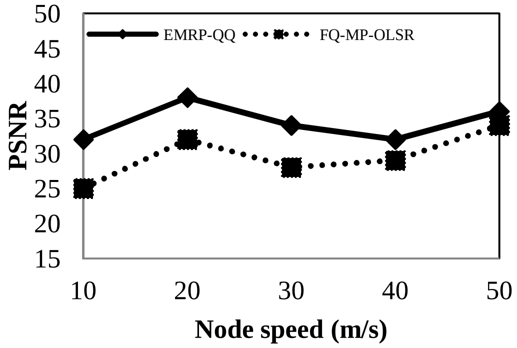
PSNR The received and original video streams are compared by frame by frame format. First compute the mean square error (MSE) of each pixel of both original and received video frames. Then the PSNR between the source (S) to destination (D) is computed from following relations and it is represented in dB (decibels).

$$PSNR(S,D) = 20\log\frac{V_{\max.\text{pixel}}}{MSE(S,D)} \tag{10}$$

where $V_{\max.\text{pixel}}$ is the maximum possible pixel value. It is analyzed by varying the node speed and constant node with two different video streams such as 352×288 low quality and 1080×720 high quality is shown in figure 10a and 10b respectively. The plot clearly depicts the PSNR of proposed routing protocol EMRP-QQ is increased compare to FQ-MP-OLSR in both low and high quality.

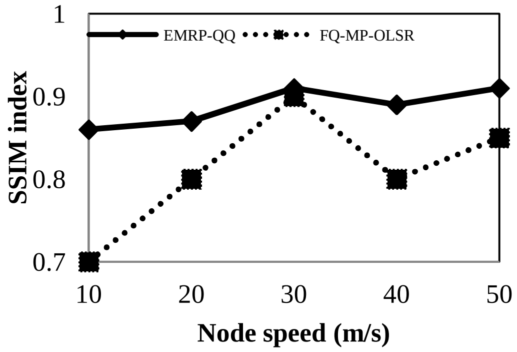


(a)

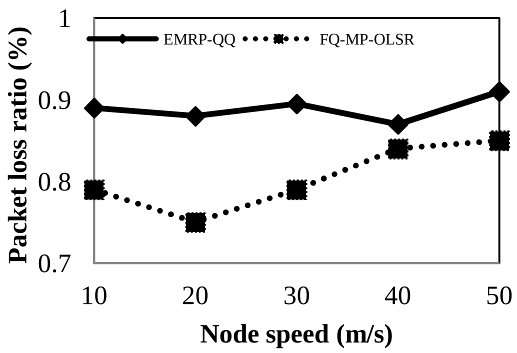


(b)

Figure 10 PSNR (a) 352×288 low quality video stream (b) 1080×720 high quality video stream



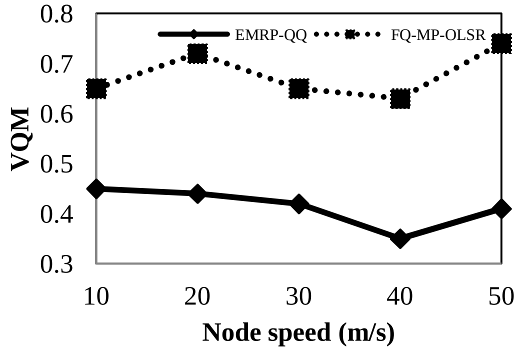
(a)



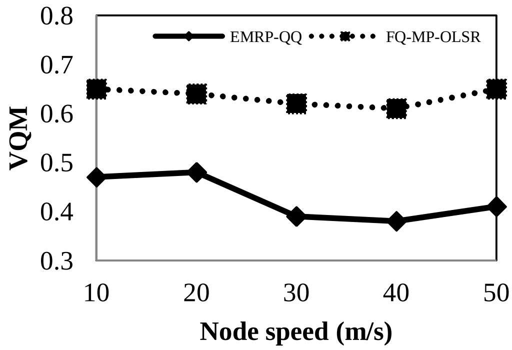
(b)

Figure 11. SSIM index (a) 352×288 low quality video stream (b) 1080×720 high quality video stream

SSIM index measures the correlation between the source and destination end using distortion of video streams and includes contrast, luminance. The SSIM index values are varying with 0 to 1, if the result values near to 1 means, it is better quality. It is analyzed by varying the node speed and constant node with two different video streams such as 352×288 low quality and 1080×720 high quality is shown in Figure 11a and 11b respectively. The plot clearly depicts the SSIM index of proposed routing protocol EMRP-QQ is increased compare to FQ-MP-OLSR in both low and high quality videos.



(a)



(b)

Figure 12. VQM (a) 352×288 low quality video stream (b) 1080×720 high quality video stream

VQM used to measure unwanted things present in video stream between source to destination. The unwanted factors include blurred effect, motion effect, different noise and distortion effect. The result of combined those effect is close to 0 means the processing video quality is good one. It is analyzed by varying the node speed and constant node with two different video streams such as *352*×288 low quality and 1080×720 high quality is shown in Figure 10a and 10b respectively. The plot clearly depicts the VQM of proposed routing protocol EMRP-QQ is reduced compare to FQ-MP-OLSR in both low and high quality videos.

6. Conclusion

In this paper we present energy efficient routing protocol for MANETs to enhance the QoS and QoE metrics (EMRP-QQ). The energy efficient PSO and fuzzy optimization approach used to compute the next node with specific goodness such as low mobility, packet loss ratio, routing cost, delay, energy consumption and high throughput. The energy consumption of the proposed routing protocol is very low compare to the previous energy aware routing protocols. The QoS metrics analysis indicates the proposed EMRP-QQ maximize the QoS metrics compare to FQ-MP-OLSR routing protocol. The quality analysis indicates the proposed EMRP-QQ maximize the QoE metrics compare to FQ-MP-OLSR routing protocol.

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