QRE2PM: QoS Centric, Reliable and Energy-Efficient Routing Protocol for MANET

Amulya Sakhamuru(1)
Research Scholar, Department of Computer Science
North East Frontier Technical University
Aalo (P.O), West Siang (Distt.), AP – 791001, India.

Abstract

The high pace emergence in wireless communication systems and associated applications have given rise to a number of technologies serving certain targeted application environment. Amongst major wireless communication systems, Mobile Ad-hoc Network (MANET) has emerged as a potential solution to meet communication demands even with decentralized and infrastructure-less environment. Though, MANETs have been recognized as a potential system, very few efforts have been made to augment overall routing to ensure QoS demands, energy-efficiency and reliable communication. The available MANET routing protocols employ classical clustering and single parameter based cluster head selection for data transmission, which is confined particularly for MANETs with large scale deployment and high mobility conditions. To alleviate such issues, this paper presents a highly robust QoS Centric, Reliable and Energy-Efficient Routing Protocol for MANET (QRE2PM). The proposed QRE2PM model employs grid-partitioning, dual phase centralized clustering model using Fuzzy Clustering Mean and Enhanced Expectation Maximization, multiple parameters based CH selection and signaling overhead reduction model. The use of multiple network parameters, including Inter-Node-distance, Node-Responsiveness, Residual Energy, and Signal-to-Noise Ratio for CH selection strengthens QRE2PM protocol to exhibit better performance. The performance outcomes in terms of throughput, delay, energy consumption and network efficiency reveal that the proposed QRE2PM protocol outperforms other state-of-art routing protocols.

Keywords: QoS centric routing protocol, energy-efficient, FCM Clustering, Expectation Maximization, Node-responsiveness, Centralized clustering, Multiple parameter based CH selection

1. INTRODUCTION

In recent years, the high pace rise in wireless communication technologies and associated demands have motivated researchers and scientific community to develop certain more efficient and robust routing mechanism to fulfill rising Quality of Service (QoS) demands and reliable data transmission. The efficacy of wireless communication systems for number applications comprising civil surveillance, industrial monitoring and control, automation, defense applications, inter-node communication, inter-vehicular communication etc has established it as an inevitable need of present day human society. Furthermore, the recently emerged technique called “Internet of Things (IoT) ecosystem” has given rise to a broad dimension of wireless communication system that require QoS efficient and reliable data transmission over static as well as mobile networks. Among major wireless communication technologies, Mobile Ad-hoc Networks (MANETs) has emerged, as a vital paradigm to meet decentralized and infrastructure communication demands. Mobility assisted Ad-hoc communication enables MANETs to serve an array of applications ranging sophisticated inter-vehicular communication to the inter-node communication for natural calamity. MANETs contain multiple nodes distributed across the network. Typically, these nodes function in cooperative and collaborative approach to perform inter-node communication among the deployed nodes to make intended decision. In this approach, the deployed Ad-hoc nodes collect data from the neighboring nodes and perform multi-hop communication to forward data to the destination or the sink node. However, being a dynamic topology based routing model, MANETs undergo numerous adversaries causing significantly high link outage, data drop, retransmission etc causing eventually delay and energy exhaustion. Additionally, it degrades QoS delivery over network.

The dynamic topology of MANETs requires efficient routing model to ensure reliable and delay resilient communication to make early and efficient decision. To meet QoS demands, MANET routing protocol requires enabling low cost solution, minimum delay, minimum latency, higher communication reliability and minimum signaling overheads. In major MANET applications, enabling QoS delivery needs timely and reliable data gathering at the sink while ensuring minimum latency, end-to-end delay, and energy consumption and signaling overheads. In practice, data transmission in MANETs comprises traversal from source to destination through multiple hops that during dynamic topology imposes
significantly high link outage probability. Under such circumstances employing the best forwarding path plays decisive role to ensure reliable data transmission. In addition, dynamic topology often imposes threat of link outage probability and hence reliable transmission over MANETs. Under such circumstances, QoS assurance, particularly timely data delivery under Mission Critical Communication (MCC) application remains suspicious. Under dynamic topological condition ensuring link reliability could be of utmost significance for which node responsiveness assessment can be a potential solution. In major existing protocols the node table management often imposes significantly high signaling overheads to perform reliable or fault resilient communication. However, such approaches perform at the cost of increased energy consumption and delay which adversely affect QoS delivery for MCC purposes. Therefore, reducing signaling overheads, excessive multihop transmission and link outage probability could be the vital factors to ensure reliable data transmission over MANETs.

In majority of the existing MANET protocols such as AODV, DSR, LEACH or enhanced LEACH the researchers have exploited the efficacy of clustering technique to perform data transmission. However, not much significant effort is made to augment overall operating components of clustering based MANETs, such as Clustering or Cluster Head (CH) selection enhancement. In few researches authors have applied network parameters such as inter-node distance, residual energy, Signal to Noise Ratio (SNR) parameter to perform CH selection; however node responsiveness under dynamic topology has not been explored so far. Furthermore, existing researches primarily emphasize on CH selection and could not deal with clustering optimization or signaling cost optimization, which could have augmented overall network’s performance. It has been found that enhancing clustering reliability can be vital for minimizing signaling overhead and energy exhaustion. Considering these limitations as motivation, in this research paper a highly robust and efficient routing protocol named QoS Centric and Reliable and Energy-Efficient Routing Protocol for MANETs (QRE2PM).

The presented research work exploits major technologies including grid partitioning, enhanced multi-phase Centralized Clustering Paradigm (CCP) optimization using Fuzzy Clustering Mean (FCM) and Enhanced Expectation Maximization (EEM), Degree of Dependence (DoD) based link reliability assessment and multiple parameter based CH selection. The overall proposed model is simulated using Network Simulator tool (NS2) and the results revealed that QRE2PM protocol can achieve higher throughput, minimum latency or end-to-end delay and higher efficiency than other state-of-art MANET routing protocols. Table I depicts the abbreviations that are used in the paper.

### TABLE I: List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>MANETs</td>
<td>Mobile Ad-hoc Networks</td>
</tr>
<tr>
<td>MCC</td>
<td>Mission Critical Communication</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal to Noise Ratio</td>
</tr>
<tr>
<td>QRE2PM</td>
<td>QoS Centric and Reliable and Energy-Efficient Routing Protocol for MANETs</td>
</tr>
<tr>
<td>CH</td>
<td>Cluster Head</td>
</tr>
<tr>
<td>FCM</td>
<td>Fuzzy Clustering Mean</td>
</tr>
<tr>
<td>EM</td>
<td>Expectation Maximization</td>
</tr>
<tr>
<td>TSP</td>
<td>Travelling Salesman Problem</td>
</tr>
<tr>
<td>CCP</td>
<td>Centralized Clustering Paradigm</td>
</tr>
<tr>
<td>DoD</td>
<td>Degree of Dependence</td>
</tr>
<tr>
<td>EEM</td>
<td>Enhanced Expectation Maximization</td>
</tr>
<tr>
<td>NS2</td>
<td>Network Simulator tool</td>
</tr>
<tr>
<td>AF</td>
<td>Amplify-and-Forward</td>
</tr>
<tr>
<td>DCFP</td>
<td>Dynamic Connectivity Factor Routing Protocol</td>
</tr>
<tr>
<td>WSEEC</td>
<td>Weightage based Secure Energy Efficient Clustering</td>
</tr>
<tr>
<td>FF-AOMDV</td>
<td>Fitness Function based Ad Hoc on Demand Multipath Distance Vector</td>
</tr>
<tr>
<td>QRE2PM</td>
<td>QoS Centric, Reliable and Energy-Efficient Routing Protocol for MANETs</td>
</tr>
<tr>
<td>CCM</td>
<td>Centralized Clustering Model</td>
</tr>
<tr>
<td>GMM</td>
<td>Gaussian Mixture Model</td>
</tr>
<tr>
<td>CM</td>
<td>Covariance Matrix</td>
</tr>
<tr>
<td>CoG</td>
<td>Center of Gravity</td>
</tr>
<tr>
<td>SoS</td>
<td>Sum of Square</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indicator</td>
</tr>
<tr>
<td>VANETs</td>
<td>Vehicular Ad-hoc Networks</td>
</tr>
<tr>
<td>TSP</td>
<td>Travelling Salesman Problem</td>
</tr>
<tr>
<td>PTR</td>
<td>Packet Transmission Request</td>
</tr>
<tr>
<td>TRM</td>
<td>Transmission Request Message</td>
</tr>
<tr>
<td>IDVR</td>
<td>Intersection Dynamic VANET Routing</td>
</tr>
<tr>
<td>CBLTR</td>
<td>Cluster-Based Life-Time Routing</td>
</tr>
<tr>
<td>CORA</td>
<td>Control Overhead Reduction Algorithm</td>
</tr>
</tbody>
</table>

The other sections of the presented thesis are divided as follows. Section II discusses the related work, while the proposed routing protocol (i.e., QRE2PM) is discussed in Section III. Section IV discusses the results obtained and its significances, while the overall research conclusion is presented in Section V. References used in this paper are given at the end of the manuscript.
2. RELATED WORK

This section briefs some of the key literatures pertaining to MANET’s routing protocol.

To enable QoS delivery over MANETs, Fang et al. [1] exploited the affect of buffer constraint and packet lifetime on network performance. They derived a Markov chain concept based model to provide input rate-dependent throughput and packet loss ratio for QoS assurance. Chen et al. [2] developed a multicast routing protocol by deriving multiple multicast trees and network coding for lossy MANETs. In this approach the individual multicast tree satisfies a predetermined fraction of the bandwidth need. The use of network coding enabled bandwidth efficiency and minimum redundant packets. Khan et al. [3] focused on identifying malicious nodes by exploiting network parameters signifying whether packet losses are because of queue overflows or node mobility. Komai et al. [4] developed Filling Area (FA) concept to execute KNN queries in the MANETs so as to reduce overhead in query processing by minimizing search area. Noticeably, in FA concept, data often remain at the node nearing the locations with which the data attribute is allied with. In addition, nodes cache data attributes near their own location that enables KNNs to process queries from nearby nodes. Jia et al. [5] assessed delay and network capacity of MANETs, by applying node-correlation concept during mobility. Authors exploited inter-node relationship under mobility to understand the impact of mobility on the network performance. Luo et al. [6] applied Random Linear Coding (RLC) to achieve throughput-delay tradeoff in MANET. Authors explored the supplementary infrastructure to facilitate transmission pipes in between the remotely placed nodes. Based on study, they derived an asymptotically optimal throughput-delay tradeoff which was further applied to perform transmission scheduling. Hu et al. [7] examined Amplify-and-Forward (AF) relaying approach for performance optimization under Rayleigh fading condition in MANETs. A similar effort was made by Liu et al. [8] who emphasized on two-hop relay MANETs with bandwidth constrained scenarios and mobility. They focused on delay tolerant communication over MANETs. A fault tolerant and QoS centric look-ahead routing model was developed by Surendran et al. [9] that at first identifies suitable route and look-ahead route pairs to form alternate path during valid link outage. To avoid link outage and RREQ signaling overhead, Ejmaa et al. [10] developed neighbor-based Dynamic Connectivity Factor routing Protocol (DCFP) that assesses underlying network condition by means of novel connectivity metric.

Authors [11][12] have found that clustering based routing protocol could be of paramount significance for MANETs. Considering efficacy of clustering based MANET’s routing protocol, Authors [11][13] developed a lightweight dynamic channel allocation scheme for cooperative load balancing in MANETs. Similar effort has been done in [21-24]. Kaur et al. [14] too developed Weightage based Secure Energy Efficient Clustering (WSEEC) routing protocol to achieve energy-efficient routing over MANETs. Authors applied residual energy to identify best and reliable CH. Saxena et al. [12] too backed up clustering based routing protocol for energy efficient MANETs. Additionally, they applied grid partitioning concept to achieve self-organizing cluster formation for delay resilient and energy-efficient routing. Authors applied energy based max-heap concept in which the node with the highest energy level in cluster was selected as CH. Kidston et al. [15] developed k-hop cluster based data dissemination model to piggyback on routing messages for detecting link outage over MANETs. In this model, applying spanning tree concept, nodes forward their neighborhood information to a cluster failure detector that consequently tries to avoid data routing to the fault path. Literatures reveal that in MANETs, selfish nodes or the intruders often causes data replication or drop that consequently imposes huge transmission cost and energy exhaustion. To alleviate it for timely data delivery Zeng et al. [16] focused on selfish node identification to avoid routing issues in CH selection. To perform intrusion detection authors applied clustering technique. Authors found that selfish node in clustering often impose data loss causing retransmission, delay and energy exhaustion. Alinci et al. [17] developed different types of clustering algorithms like Mobility-based clustering, Energy-efficient clustering, Connectivity-based clustering, and Weighted-based clustering for MANETs routing functions. Authors applied Fuzzy logic to augment node reliability under dynamic topology conditions. Zhou et al. [18] developed an on-demand clustering model by exploiting weighted parameters to perform CH selection and clustering. Noticeably, unlike conventional clustering models where the absolute speed is used authors applied weighted parameter to maintain the structure of cluster by applying the relative movement speed.

In MANETs mobility and resulting topological changes impose significantly high network vulnerability. To alleviate it, Son et al. [19] focused on detecting mobile nodes so as to derive a self-adapt routing protocol for MANETs. To achieve energy efficient routing Taha et al. [20] developed a Fitness Function based Ad Hoc on Demand Multipath Distance Vector (FF-AOMDV) routing protocol. In their model the fitness function was applied to estimate the optimal path from source to sink node so as to minimize energy consumption in multipath routing. Recently, a few efforts were made to incorporate clustering based routing model for MANETs [25-37]. However, these approaches could not address the problem of signaling overheads, and clustering optimization. Most of these approaches applied merely single parameter to perform
CH selection that confines suitability or applicability of these models in real-time application with higher mobility condition.

3. SOLUTION AND PROSPECT

This paper proposes a highly robust and efficient routing protocol named QoS Centric, Reliable and Energy-Efficient Routing Protocol for MANETs (QRE2PM). Literatures reveal that the majority of exiting MANETs routing protocols have applied clustering based routing to achieve energy efficient and reliable transmission over MANETs. Though, a few efforts have been made to explore clustering based routing protocol, no vital effort is made to enhance the number of clusters, signaling overhead, control message transmission, reliable link formation or link outage resilient forwarding path selection, multiple parameters based CH selection etc. In majority of existing approaches single parameter based CH selection has been done that confines efficacy of the routing model to deal with dynamic topology and varying network state parameters. Unlike classical routing protocols, in this paper an enhanced Centralized Clustering Model (CCM) has been developed that in conjunction with an augmented multiple parameters based CH selection exhibits data communication over MANETs. In addition, this work proposes a multiple parameters based CH selection model by using residual energy, inter-node distance, link reliability, node responsiveness etc to perform CH selection. Furthermore, the proposed QRE2PM model is supplemented with inter-node distance and link responsiveness based strategy for fast data transmission and deadline sensitive (forwarding) path formation for MANETs.

The proposed CCM model ensures minimum number of clusters that eventually intend to reduce overall signaling overheads and control signal requirements. To embrace the proposed routing model for real-time large-scale MANET application, QRE2PM routing protocol at first performs grid-partitioning followed by enhanced clustering and CH selection for efficient communication. The overall proposed routing protocol intends to ensure higher throughput, minimum energy consumption, end-to-end delay, packet drops, bandwidth utilization and higher efficiency. The following sub-section briefs the proposed QRE2PM protocol and its implementation to achieve QoS centric and energy-efficient communication over MANETs. Typically, MANETs are deployed over a large distributed area comprising multiple nodes distributed across the considered geographical locations. Under such circumstances, retaining intact link amongst different nodes becomes intricate task. To avoid such issues, applying Grid Partitioning can be of vital significance.

With this motivation, in this paper the proposed QRE2PM routing protocol at first performs grid partitioning which is then followed by the multiple phased CCM clustering and multiple parameters based CH selection.

The overall proposed model comprises the following key contributions:

1. MANET Grid Partitioning,
2. Enhanced Multi-phased Clustering using Fuzzy Clustering Mean and Enhanced Expectation Maximization,
3. Node Responsiveness Based Clustering Optimization,
4. Multiple Network Parameters Based CH selection,
5. Cooperative Communication Assisted Data Transmission,
6. Control Packet Optimization or Signaling Overhead Reduction.

Considering practical node deployment in MANETs where there could be a large number of nodes distributed across network region, our proposed routing protocol at first exhibits grid partitioning where the network region is divided into small regions (i.e., the groups containing multiple nodes). This approach alleviates the possibility of abrupt link disruption, high multi-hop transmission, excessive energy consumption and helps in efficient network management. As stated, unlike classical clustering approaches, QRE2PM applies a double phased clustering that enables optimal link reliability during further data transmission and signaling overhead reduction. As stated above, QRE2PM at first applies FCM based clustering which is then followed by the implementation of Expectation Maximization based CCM. Undeniably, most of the existing routing protocols have applied inter-node distance factor to perform clustering; however no significant work addresses the link-volatility issue and its impact during mobility in MANETs. To fill this gap, the second phase of the proposed clustering model applies a parameter called Degree-of-Dependence (DoD) between nodes to perform clustering. The key significance of Expectation Maximization is to ensure optimal responsiveness between nodes to perform reliable data transmission over MANETs. Furthermore, it minimizes the number of clusters that eventually reduces signaling overheads. To further augment the routing strengths, in QRE2PM routing protocol the focus is made on CH selection optimization where in stead of single parameter based CH selection, multiple parameters have been considered. In our proposed CH selection model the key parameters considered are inter-node distance, inter-node responsiveness, residual energy, and signal to noise ratio. In addition to the aforementioned contributions, QRE2PM implements a dual mode transmission strategy that exploits inter-node distance parameters to perform alternate path selection for data transmission. It intends to reduce end-to-end delay so as to support QoS delivery.
The detailed discussion of the proposed QRE2PM routing protocol is given as follows:

**Network Design**

In this research work, considering real-time large-scale MANET application the network with a large number of nodes has been taken into consideration. The considered nodes have their respective radio (or communication) range. The deployed network resembles real time communication environment such as inter-vehicular communication environment, battlefield, harbor monitoring and surveillance systems, natural calamity rehabilitation and restoration activities etc. Considering the inevitable significance of reliable and timely data communication under aforesaid application environment, enabling seamless communication is of utmost significance. To avoid exceedingly high signaling overheads and multi-hop transmission QRE2PM applies grid-partitioning concept that splits overall network into multiple small size sub-networks called “Group” (Fig. 1). In Fig. 1 circles present the deployed N nodes across the network with P × Q dimension. On the other hand, the solid color circle C represents CH selected for each cluster that exhibits data forwarding to the next hop to let it reach the destination. The other solid color circles present the other connected nodes in the deployed network. Here (Fig. 1), the dotted circles signify the clusters formed. As stated, in the proposed network model, connected nodes within a “Group” can communicate only with the nodes within that cluster and the nodes pertaining to other Groups can’t communicate with each other. In other words, the nodes within a “Group” are able to communicate with only those nodes within that Group. Let, T_g be the total number of “Groups” constituted after grid-partitioning of the MANET and C_n be the total connected nodes. Consider, T_c be the total number of clusters formed in T_g,th Group. In majority of traditional routing models the number of Groups is estimated by means of certain statistical approach. On contrary, QRE2PM exploits node position and inter-node connectivity to perform Grid-partitioning that ensures reliable and QoS centric communication over MANETs.

In proposed routing model it is assumed that each node is aware of its location, residual energy, Inter-Node-Dependency or DoD etc, which are further shared amongst connecting nodes to perform CH selection. These key metrics could be obtained by means of certain node location algorithm and per-bit energy consumption estimation model. Since, each node has a fixed communication range R, it can communicate with the nodes within falling within the radio range R. QRE2PM assumes that each comprising node has a fixed buffer to store and forward the data towards the destination. In the deployed network each node pertaining to a cluster field estimates key parameters such as inter-node distance, DoD between nodes, each node responsiveness factor and residual energy etc. These estimated node states information is used to perform CH selection for each cluster. In practice, each node exchanges their respective node information that helps in proactive CH selection during communication. To achieve QoS centric and energy-efficient routing over MANETs, QRE2PM performs multi-level optimization at the different stages of routing and communication.

The detailed discussion of the proposed routing model and its implementation is given as follows:

### 3.1 Dual Phase Clustering

In most of the generic clustering methods authors have applied node-distance to perform clustering; however under dynamic topology conditions that is common in MANET consideration of inter-node distance as threshold for clustering can’t be optimal. Single parameter based clustering under dynamic topology could cause iterative link outage resulting into data drop and QoS violation. However, the use of inter-node distance can be a potential approach to perform clustering. In addition, the use of link reliability or node responsiveness could also be vital to ensure reliable data transmission under dynamic topology of MANETs. With this motivation, in this paper QRE2PM applies a dual phase clustering by means of FCM and EEM approaches. Our proposed QRE2PM protocol applies the following two clustering models in sequence to perform CCM.

**Step-1:** Fuzzy Cluster Mean (FCM) based clustering and

**Step-2:** DoD based Enhanced Expectation Maximization for CCM.

![Figure 1: Deployed MANET](image-url)
A snippet of the applied clustering model is given as follows:

3.1.1 Step-1 FCM Assisted Clustering

As already stated, in our proposed QRE2PM routing model each node is aware about its position and shares its node information amongst the nodes pertaining to the same Group. Performing Grid-partitioning QRE2PM performs FCM based initial that exploits inter-node distance or node-position information to perform clustering. In this model, the nodes closer to each other intend to be a part of cluster. As, FCM is found efficient for pattern recognition and classification; its robustness enables clustering by providing membership to each node belonging to a cluster. Here, the addition of all membership is one (Eq. (1)). To perform clustering in our proposed QRE2PM routing model FCM applies the following objective function, which is expected to be minimum to perform efficient clustering (1).

\[
\min_{d_{ij}, d_j} (u_p), 
\]

Where

\[
u_p = \sum_{i=1}^{N} \sum_{j=1}^{M} d_{ij}^p \| \theta_i - d_j \|^2,
\]

In QRE2PM protocol, the node deployment is signified in terms of a network graph G having vertex joining each node. Here each vertex states the node’s position in two dimensional (2D) spaces. In other words, the node position for the \(i\)th node can be defined as \(\theta_i = [X_i, Y_i]^T\). Thus, in Eq. (2), \(\theta_i\) stated 2D location vector for the \(i\)th node. The other variable \(d_j\) states the \(j\)th node position in the \(d\)th cluster. In Eq. (3) \(T_c\) represents the total number of clusters formed. Noticeably, in our model the fuzziness exponent factor \(p\) is always greater than 1. The variable \(d_{ij}\) states the level of membership of the \(i\)th node in \(j\)th cluster and \(C_j\) refers the center of \(j\)th cluster. The other variable in Eq. (3), \(C_k\) signifies center of the \(k\)th cluster. Noticeably, \(d_{ij}\) remains in between 0 and 1 for each node pertaining to the connected CH. QRE2PM protocol at first executes fuzzy partitioning in conjunction with a continual optimization method where it intends to minimize the derived objective function (Eq. (3)) iteratively.

\[
d_{ij} = \frac{1}{\sum_{h=1}^{T_c} \left( \frac{\| \theta_i - C_h \|}{\| \theta_i - C_h \|} \right)^{2p-1}},
\]

In this manner, CH of the \(j\)th cluster, \(C_j\) is obtained using Eq. (4).

\[
C_j = \frac{\sum_{i=1}^{N} d_{ij}^p \theta_i}{\sum_{i=1}^{N} d_{ij}^p}.
\]

This optimization process continues till the stopping criterion is met. Noticeably, QRE2PM applies the following stopping criteria (Eq. (5)) for sub-optimal solution retrieval.

\[
\{d_{ij}^{k+1} - d_{ij}^k\} < \rho
\]

In above equation (5), \(k\) signifies the iteration.

The pseudo code for proposed FCM based clustering is given in Fig. 2.

Algorithm-1 FCM assisted initial clustering in QRE2PM

Initialization: Membership value for each node \(d_{ij} \forall h = 1, 2, \ldots M \forall i = 1, 2, \ldots N\)

Initialized cluster centers.

\[
\text{while} \{d_{ij}^{k+1} - d_{ij}^k\} < \rho \text{ do}
\]

\[
\text{for } j = 1, 2, \ldots M \text{ do}
\]

\[
C_j = \frac{\sum_{i=1}^{N} d_{ij}^p \theta_i}{\sum_{i=1}^{N} d_{ij}^p}
\]

\[\text{end for}\]

\[
\text{for } i = 1, 2, \ldots N \text{ do}
\]

\[
\text{for } j = 1, 2, \ldots M \text{ do}
\]

\[
\text{if} \| \theta_i - C_j \| > 0 \text{ then}
\]

Calculate \(d_{ij}\) as

\[
\mu_{ij} = \frac{1}{\sum_{h=1}^{M} \left( \frac{\| \theta_i - C_h \|}{\| \theta_i - C_k \|} \right)^{2p-1}}
\]

That is \(d_{ij}^{k+1}\)

\[\text{end if}\]

\[\text{end for}\]

\[\text{end for}\]

\[\text{end while}\]

Figure 2: FCM assisted initial clustering in QRE2PM
Though, FCM assisted clustering enables the formation of clusters with only those nodes, which are close enough to perform communication; under mobility the probability of link-outage often remains dominating. Under such circumstances, augmenting clustering with certain inter-node responsiveness could help in avoiding link outage probability. With this motivation, in this paper an enhanced CCM algorithm called Enhanced Expectation Maximization (EEM) has been developed. EEM algorithm estimates DoD between nodes to enhance clustering. A snippet of the proposed EEM based CCM is given as follows:

3.1.1 | Step-2 Enhanced Expectation Maximization (EEM) Assisted Centralized Clustering

EEM is one of the robust centralized clustering models [k-KONID][PEGASIS], where it is assumed that all participating nodes are distributed as per Gaussian Mixture Model (GMM) as given in Eq. (6).

\[ G(x) = \sum_{c=1}^{C} \rho_c \text{EEM}(y|\rho_c, \epsilon_c) \] (6)

where, \( C \) and \( \rho_c \) states the total number of clusters and a combination factor for the \( c \)th cluster, respectively. In this model, \( \text{EEM}(y|\rho, \epsilon) \) is obtained using Eq. (7).

\[ \text{EEM}(y|\rho, \epsilon) = \frac{1}{(2\pi |\epsilon|)^{1/2}} \exp \left\{ -\frac{1}{2} (y - \rho)^T \epsilon^{-1} (y - \rho) \right\}, \] (7)

In Eq. (7), variables \( y \) and \( \rho \) signify the position vector of the connected nodes and CH of the cth cluster, subsequently. Here, \( \epsilon_c \) signifies a \( 2 \times 2 \) Covariance Matrix (CM) of \( c \)th cluster. Considering dynamic topology of MANETs, our proposed QRE2PM routing model examines DoD between nodes to ensure optimal connectivity or fault-resilient link formation during data transmission. In above expression \( N \) signifies the node responsiveness that signifies responsiveness of a node with other connected nodes in cluster. QRE2PM applies Eq. (8) to estimate node responsiveness of node \( n \) on \( k \)th cluster.

\[ \delta_{nc} = \frac{\rho_c b(y_n|\rho_c, \epsilon_c)}{\sum_{c=1}^{C} \rho_c b(y_n|\rho_c, \epsilon_c)} \] (8)

In practice, the value of node responsiveness often exists in between 0 and 1.

Once performing FCM based initial clustering and retrieving the node position of the CHs as well as connected-node position, the inter-node distance parameter is estimated. In addition, EEM model calculates two different position vector \( (\rho) \) and covariance matrix\( (\epsilon) \), which are used for cluster optimization. As already stated in above sections, to deal with the large scale MANETs grid-partitioning is performed where our proposed QRE2PM model applies Eq. (9) to estimate the number of “Groups”.

\[ N_s = \frac{T_c}{C_n} \] (9)

In Eq. (9), \( T_c \) states the total number of clusters while \( C_n \) signifies the total number of nodes in a group. Here, in these constructed groups, the node-responsiveness \( \delta_{nc} \) of all connected nodes is estimated and node with the highest \( N_s \), are updated. In above expression (Eq. (9)) the node responsiveness factor \( \delta_{nc} \) refers the level to which a participating (MANET) node \( n \) is dependent on the cluster. Estimating \( \delta_{nc} \) we re-estimate the value of \( \rho \) and \( \epsilon \) and in this manner applying \( \delta_{nc} \) the total number of nodes belonging to a cluster is obtained using Eq. (10).

\[ NC_n = \sum_{x_n \in X} \delta_{nc} \] (10)

In above expression Eq. (10), \( NC_n \) refers the total number of nodes in a cluster. This model helps in optimal node distribution across the clusters and hence reduces the number of clusters to be formed in considered network area. Here, EEM model applies a factor \( C \) signifying weighted Center of Gravity (CoG) of a two-dimensional position vector which is usually obtained for each participating node. To estimate CoG, initially the node responsiveness value, \( \delta_{nc} \) for each participating node is obtained and the position of CH is changed through the estimated weighted-CoG value. In QRE2PM EEM estimates the log-probability so as to obtain the optimal number of clusters using Eq. (11).

\[ E = \ln G(Y|\rho, \epsilon, \rho) = \sum_{n=1}^{N} \ln \left( \sum_{c=1}^{C} \rho_c \text{EEM}(y_n|\rho_c, \epsilon_c) \right) \] (11)

In our proposed QRE2PM routing protocol, EEM algorithm executes clustering optimization till convergence. Here, the value of \( \epsilon \) in Eq. (11) reduces abruptly that saturates EEM in pre-mature stage. In our proposed EEM model the continuous information update is performed for \( \rho_c \) and \( \delta_{nc} \) of each participating node pertaining to the cth cluster and thus minimizes Sum of Square (SoS) of the distance between the connected nodes and the cluster center. This process ensures the optimal cluster formation and node distribution across clusters. This overall process of clustering ensures that the optimal number of clusters is formed and best possible node distribution is done across the clusters with maximum connectivity and reliability to support QoS centric communication over MANETs. In this model as the number of clusters are reduced, it suppresses the signaling overheads and control packet transmission.

Once performing dual-phase clustering, QRE2PM executes CH selection where it exploits multiple network parameters to
perform optimal CH selection. A brief of the CH selection method applied is given as follows:

### 3.2 Cluster Head (CH) Selection

In CCM-based routing approaches, the selection of CH often play vital role. In majority of the existing models, single network parameter like inter-node distance or the distance between connected nodes and CH, per node residual energy, link quality etc are used to perform CH selection. On contrary, in practice under mobility condition network topology keeps on changing that eventually results into continual network states or parameter variation. Under such circumstances, performing CH selection based on single parameter could be inefficient. Considering this fact, in this paper QRE2PM protocol applies multiple network parameters to perform CH selection. Unlike traditional approaches where single network parameters such as network lifetime [38], residual energy, SNR or Received Signal Strength Indicator (RSSI) are used for CH selection, QRE2PM applies multiple parameters including SNR, Inter-Node-Distance or node position information, Node Responsiveness, and SNR to perform CH selection. In this manner, QRE2PM intends to exploit almost all factors influencing reliability and timely data delivery over MANET. Here, the use of Inter-Node-Information enables QRE2PM to ensure that the selected CH is within the radio range and optimal connectivity to ensure reliable data transmission. The selection of a node as CH with proximity to each connected node assures that there would not be any link outage and packet drop. It augments reliability during data transmission. Similarly, the use of residual energy, which is directly linked with the node lifetime as CH decision variable ensures that the node will assure successful data delivery without getting died during transmission. Interestingly, Node Responsiveness factor as CH selection criteria enables QRE2PM that a node with higher responsiveness and inter-node dependency could assure reliable link formation (in other words, fault-robust link formation) for QoS centric data transmission. Considering these all variables, in this paper a Fuzzy logic Controller that learns selection criteria enables QRE2PM to ensure that the selected CH is within the radio range and optimal connectivity to ensure reliable data transmission. Considering these all variables, in this paper a Fuzzy logic Controller that learns selection criteria enables QRE2PM to ensure that the selected CH is within the radio range and optimal connectivity to ensure reliable data transmission.

#### Table II: Parameters for CH Selection

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-Node-Distance</td>
<td>Low</td>
</tr>
<tr>
<td>Node-Responsiveness</td>
<td>High</td>
</tr>
<tr>
<td>Residual Energy</td>
<td>High</td>
</tr>
<tr>
<td>SNR</td>
<td>High</td>
</tr>
</tbody>
</table>

In QRE2PM FLC learns the network parameters to derive an objective function (Eq. (12)).

$$\omega_i^{(k)} = \max_{\text{CH}} \left( \frac{\text{RE}_i^{(k)} \cdot \text{MS}_i^{(k)} \cdot \delta_i^{(k)}}{\beta \text{PD}_i^{(k)} + (1 - \beta) \text{PD}_{\text{MS}}^{(k)}} \right)$$  \hspace{1cm} (12)

In Eq. (12) $\delta_i^{(k)}$ states Node-Responsiveness factor, $\text{RE}_i^{(k)}$ signifies residual energy of ith node, while $\text{MS}_i^{(k)}$ refers SNR between ith connected participating node and destination. In addition, it exploits inter-node-distance to perform CH selection. In Eq. (12), the variable $\text{PD}_i^{(k)}$ in denominator states the mean path loss in between ith participating node and other nodes. The other variable, $\text{PD}_{\text{MS}}^{(k)}$ signifies the path loss exponent of the ith node and the destination and $\beta$ presents a weight parameter assigned to $\text{PD}_i^{(k)}$ and $\text{PD}_{\text{MS}}^{(k)}$. In the proposed model, the value of $\beta$ is assigned in the range of 0 to 1. To perform fault-robust data transmission over MANETs the Inter-Node-Distances between participating nodes and allied CH have been kept low that supports higher connectivity. In our proposed routing model the value of $\text{PD}_i^{(k)}$ is estimated using Eq. (13).

$$\text{PD}_i^{(k)} = \frac{\sum_{l=1}^{T_m} \text{PD}_{ij}^{(k)}}{T_m}$$ \hspace{1cm} (13)

In Eq. (13), the variable $T_m$ signifies the total number of nodes pertaining to the mth cluster. The path loss between ith and jth node is estimated as $\text{PD}_{ij}^{(k)}$ using Eq. (14).

$$\text{PD}_{ij}^{(k)} = 10 \log_{10} \left( \frac{D_{ij}^{(k)}}{D_{ij}^{(k)}} \right)$$ \hspace{1cm} (14)

In Eq. (14), $D_{ij}^{(k)} = \left\| \theta_i^{(k)} - \theta_i^{(k)} \right\|$ presents the Inter-Node-distance between jth node and CH, where the position of ith CH is obtained as $\theta_i^{(k)} = \left\{ \hat{p}_i^{(k)}, q_i^{(k)} \right\}$. In similar way, the position of jth node can be obtained as $\theta_j^{(k)} = \left\{ \hat{p}_j^{(k)}, q_j^{(k)} \right\}$, where $n$ presents the path loss exponent. The path loss between destination node and CH is estimated using Eq. (15).

$$\text{PD}_{\text{MS}}^{(k)} = 10 \log_{10} \left( D_{\text{MS}}^{(k)} \right)$$ \hspace{1cm} (15)

In Eq. (15), $D_{\text{MS}}^{(k)} = \left\| \theta_i^{(k)} - \theta_{\text{MS}} \right\||$, with $\theta_{\text{MS}} = \left\{ p_{\text{ms}}, q_{\text{ms}} \right\}$. Here, $\theta_{\text{MS}}$ signifies the position of destination node. Thus,
executing FLC for network parameters learning, QRE2PM employs conditions (Fig 3) and exhibits CH selection. The pseudo-code for FLC based CH selection is given as follows:

**Algorithm-2 FLC Assisted CH Selection in QRE2PM**

Initialize CH selection

while $k = 1, 2, \ldots, K$ do

Select initial CH for $k$th Cluster

for $j = 1, 2, \ldots, N_{m,l}$ do

Calculate $RE_i^{(k)}$, $\mu_i^{(k)}$, $\delta_i^{(k)}$, $PD_i^{(k)}$ and $PD_{MS}^{(k)}$

Initiate FIS learning and classification

if $\omega_i^{(k)} = \max_{CH} \left( \frac{RE_i^{(k)} \cdot \mu_i^{(k)} \cdot \delta_i^{(k)}}{PD_i^{(k)} \cdot (1-\beta)PD_{MS}^{(k)}} \right)$ then

$m$th CH ← $i$th sensor

else

Cluster member ← $i$th sensor

end if

end for

end while

3.3 |Cooperative Communication Assisted Data Transmission

As stated, QRE2PM intends to implement multilevel optimization measure to ensure optimal performance in MANET communication it incorporates a novel transmission strategy, where CH exploits distance between CH and other neighboring node to form a forwarding path. In this method, the neighboring CH shares its position vector with other CH, which is later used to decide forwarding path towards destination. In our proposed QRE2PM routing model the path with minimum distance is preferred for data forwarding. To perform it, once exhibiting CH selection the selected CH starts multicasting a beacon message that after receiving neighboring node acknowledges (ACK) with current position vector. Thus, estimating the link with minimum distance, QRE2PM schedules data transmission over MANET. Though, to ensure reliability during transmission, mobility control function could also be applied; however considering typical mobility characteristics in MANETs, such as Vehicular Ad-hoc Networks (VANETs), mobility control can’t be suggested as nodes (here, vehicles) follows self-controlled movement pattern. However, in other application environment such as MANETs for natural calamity and restoration mobility control could be performed. In such applications, mobility control could be performed using different methods such as Travelling Salesman Problem (TSP). In our proposed method, CHs unicasts packets to the destination, where to gather data, destination node beacons Packet Transmission Request (PTR) message to all deployed CHs that forward PTR to the connected nodes. Once receiving PTR message the participating nodes acknowledge with transmission request and forward data to the destination. This approach could significantly reduce the signaling overheads and energy exhaustion due to more multihop transmission. In QRE2PM protocol to reduce energy consumption and enhance transmission reliability participating nodes employ two network parameters such as Inter-Node Distance and Node-Responsiveness Factor to decide suitability of a forwarding node.

In QRE2PM certain parameters $\eta, p, \epsilon$ are stored in PTR message which is further transmitted to the associated CHs and destination nodes. This way of transmission imposes huge signaling overhead that consumes energy as well as resources (i.e., buffer space). To reduce this unwanted signaling overhead QRE2PM implements a novel signaling overhead optimization scheme that intends to minimize PTR transmission across MANET. A snippet of the proposed signaling overhead optimization model is discussed in following section.

3.4 |Signaling Overhead Optimization

At first CH multicasts PTR to the connected nodes (in that cluster) that in sub-sequence phase responds back with ACK to the CH. Once receiving data from the participating nodes QRE2PM forces CH belonging to that cluster to unicast data transmission towards the destination. In addition, in classical methods participating nodes might transmit (i.e., multicast) PTR message to the neighboring node as well that as a result could force a node to receive multiple PTR to induce transmission. In this condition, the overall network might undergo unwanted transmission and overheads (say, signaling flooding) causing significant resource utilization, network contention and energy exhaustion. To alleviate such issues, in our proposed QRE2PM protocol schedules in such manner that once transmitting the data a node transits PTR to its neighboring node in the same cluster. In this approach, receiving PTR message the participating node transmits a Transmission Request Message (TRM) to the allied CH, which is then followed by the data transmission. Furthermore,
realizing the fact that in cluster based routing protocol, the number of clusters is fixed however due to increase in mobility connectivity increases significantly that as a result increases signaling overheads. It can be visualized in conjunction with the number of clusters where higher cluster count imposes higher signaling overhead. On contrary, our proposed QRE2PM routing protocol implements dual phase clustering to confine cluster numbers, the signaling overhead gets reduced significantly. Thus, by employing aforesaid approach, our proposed QRE2PM routing protocol reduces energy exhaustion, bandwidth utilization and delay etc.

The results obtained and their respective significances are discussed in Section IV.

4. RESULTS AND DISCUSSION

Considering the significance of reliable, energy-efficient and QoS centric communication over MANETs, in this paper a robust routing protocol named QoS centric, reliable and energy efficient routing protocol for MANET (QRE2PM) was developed. Being a multilevel optimization measure, QRE2PM encompasses a number of novelties and contributions such as dual phased centralized clustering model, multiple constraints based CH selection, cooperative communication and signaling overhead reduction. Unlike traditional routing models [25-37], QRE2PM applied clustering in two phase that exploits inter-node distance in first step while node responsiveness in later phase of clustering. Here, the predominant objective was to ensure maximum possible link reliability with minimum number of clusters that as a result could reduce signaling overheads. Before clustering, grid partitioning was performed that alleviated the probable link failure over large scale (distributed) network. Once deploying the nodes and performing grid partitioning, FCM has been implemented that exploits node position information to perform initial clustering. It has been followed by the execution of EEM algorithm that exploits Degree-of-Dependence (DoD) to perform clustering optimization. In later stage, considering efficacy of multiple parameters for CH selection, QRE2PM have applied current network parameters such as residual energy, inter-node-distance, node responsiveness factor, and SNR. To perform proactive node status learning and optimal CH selection, in this paper Fuzzy Logic Controller (FLC) has been applied. It enables optimal CH selection for further data transmission towards the destination. The overall routing protocol is developed based on IEEE 802.11 standard (MAC). For simulation, a network region (say, area) of 1000m × 1000m has been defined. To induce diversity of radio range and near-real time simulation the different nodes have different radio range. A few nodes are having radio range of 60 meters while some nodes possesses 10 meter of communication range. The communication ranges of the nodes exist in the range of 10-60 meter. Node has the radio range of 100 meter. Our proposed QRE2PM routing protocol was developed using Network-Simulator (NS) platform, namely NS2, where to assess the efficiency of our proposed model the performance was assessed by varying node density. Some of the key simulation parameters and specifications considered in this research are given in Table III.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Access Control</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Nodes</td>
<td>40</td>
</tr>
<tr>
<td>Radio range</td>
<td>10-60 m</td>
</tr>
<tr>
<td>Velocity</td>
<td>40 km/h</td>
</tr>
<tr>
<td>Simulation period</td>
<td>800 sec.</td>
</tr>
<tr>
<td>Gain</td>
<td>30 dB</td>
</tr>
<tr>
<td>Link margin</td>
<td>40 dB</td>
</tr>
<tr>
<td>Path loss</td>
<td>3-5</td>
</tr>
<tr>
<td>Efficiency of RF amplifier</td>
<td>0.47</td>
</tr>
<tr>
<td>Power density of AWGN</td>
<td>-134 dBm /Hz channel</td>
</tr>
<tr>
<td>Noise Figure (Receiver)</td>
<td>10 dB</td>
</tr>
<tr>
<td>Carrier frequency</td>
<td>2.5 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>20 KHz</td>
</tr>
<tr>
<td>BER performance</td>
<td>10-3</td>
</tr>
<tr>
<td>Tx. circuit power consumption</td>
<td>98.2 mw</td>
</tr>
<tr>
<td>Rx. circuit power consumption</td>
<td>112.6 mw</td>
</tr>
<tr>
<td>Antenna gain of Transceiver</td>
<td>5 dB</td>
</tr>
<tr>
<td>Routing table exchange period</td>
<td>5s</td>
</tr>
<tr>
<td>Routing table size</td>
<td>100</td>
</tr>
<tr>
<td>Transmission rate</td>
<td>2 kbps</td>
</tr>
<tr>
<td>Packet size</td>
<td>2 kbits</td>
</tr>
<tr>
<td>Tx. probability of each node</td>
<td>0.8</td>
</tr>
</tbody>
</table>

To assess the relative performance of our proposed QRE2PM routing protocol, we have developed a reference system given in [38]. In the reference model named Intersection dynamic VANET routing (IDVR) protocol [38] that exploits enhanced clustering based MANET routing authors have tried to make major augmentation by incorporating cluster-based life-time routing (CBLTR) protocol and control overhead reduction algorithm (COR). Authors too exploited the efficacy of grid partitioning to reduce likelihood of energy exhaustion and link outage. However, CBLTR primarily emphasizes on increasing the routing stability in bidirectional segment condition. On the other hand, CORA focused on signaling packet reduction. Unfortunately, authors exploited candidate shortest path route
(SCSR) to perform CH selection, and hence under excessive mobility condition, the use of single parameter for CH selection couldn’t ensure reliability during transmission, especially for the large-scale data transmission. In this method, based on SCSR with minimum inter-node distance transmission scheduling is performed. Though, our proposed QRE2PM routing protocol intends to perform similar function as mentioned in reference system; however, unlike IDVR, it augments both the clustering as well as CH selection that cumulatively ensure higher reliability, higher throughput (Fig. 4), minimum energy consumption (Fig. 5), minimum end-to-end delay (Fig. 6), and higher efficiency (Fig. 7). The results obtained for our proposed QRE2PM routing protocol as well as the reference existing system are presented as follows.

In MANET, particularly in those applications environment where there could be varying node density over operational period such as VANETs the topology as well as node density might vary aggressively. Under such circumstances node management as well as routing decision could be highly complicated. Considering this practical fact, in this paper we have varied node density to assess performance. To perform comparative performance analysis, results have been obtained in terms of throughput, delay, energy consumption, and efficiency. Fig. 4 presents the comparative performance by both our proposed QRE2PM and IDVR in terms of throughput. Observing the result (Fig. 4), it can be revealed that our proposed QRE2PM protocol outperforms existing model due to enhanced clustering optimization, cooperative communication and highly reliable link based data transmission. The consideration of node responsiveness for cluster formation and later CH selection has ensured that a node with higher alertness and responsibility could take part in routing that eventually ensures reliable data transmission and hence minimum probability of data drop. Under such circumstances, QRE2PM need not to retransmit the data that would result into reduced energy consumption (Fig. 5).

Fig. 6 presents the overall end-to-end delay incurred during data origination and receiving at the destination node. As depicted through the results (Fig. 6), our proposed QRE2PM routing protocol exhibits lower delay than the exiting IDVR based routing. Here, minimum link outage probability and retransmission needs can be the augmenting factor to achieve minimal delay. Considering majority of the existing routing protocols (even including IDVR [38]), where residual energy or the network lifetime has been selected as decision variable for CH selection, in our proposed QRE2PM routing model we have estimated energy consumption per bit which has been applied to estimate overall energy consumption during transmission $E_{Trans}$. Noticeably, $E_{Trans}$ states the energy consumed during data transmission (till the packet is received at the destination). In QRE2PM, $E_{Dat}$ is assigned 0 when the transmitter is far away from associated CH. Here, $E_{Trans} = 0$ signifies inefficiency of the clustering model and not able to guarantee successful transmission or successful delivery. Therefore, to examine overall efficiency of our proposed QRE2PM routing protocol, we have derived a parameter named Network Efficiency, given in Eq. (16).

$$\text{Network Efficiency} = \frac{\text{(Number of connected sensor node)}}{E_{Trans}} \quad (16)$$
Thus, observing above result (Fig. 7), it can be found that the proposed QRE2PM routing protocol outperforms exiting IDVR protocol. Here, the efficacy of dual phase clustering, multiple parameters based CH selection, cooperative communication and signaling overhead reduction could be the dominating reasons for the accomplished outcomes. The overall conclusion for the presented research is given in subsequent section.

5. CONCLUSION
Considering the rising significance of Mobile Ad-hoc network in present day wireless communication system, in this paper a robust routing protocol named QoS centric, reliable and energy-efficient routing protocol for MANETs (QRE2PM) has been developed. Unlike classical routing models, the proposed QRE2PM routing model incorporates multi-level optimization measure by augmenting centralized clustering model for energy-efficient and reliable data communication. To deal with large size MANET network, at first grid partitioning concept was applied that enabled splitting it into small groups. This approach alleviated the issue of link outage or allied vulnerability. Considering the significance of an enhanced clustering model for MANETs, QRE2PM incorporated dual phase clustering where at first inter-node-distance parameter was applied by Fuzzy Clustering Mean (FCM) to perform initial clustering. In later stage, node-responsiveness or degree of dependence factor was applied by Enhanced Expectation Maximization model to perform clustering optimization. This method ensured the link reliability and minimum number of clustering while ensuring optimal connectivity for reliable data transmission over MANETs. In later stage, multiple parameters including Inter-Node-distance, Node Responsiveness, Residual Energy, and Signal-to-Noise Ratio were applied to perform CH selection. In addition, the robustness of the proposed model has enabled signaling overhead reduction. These novelties incorporated have augmented overall routing model to exhibit minimum energy consumption, minimum end-to-end delay, higher efficiency and throughput. The performance comparison with recently developed routing models revealed that the proposed QRE2PM routing protocol outperforms existing state-of-art techniques and hence can be applied for real time MANET’s application environment.

REFERENCES


