EEQRPI-MRP: A Quality of Service Based Interference Aware Multipath Routing Protocol for MANETs

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Abstract

Mobile Ad-hoc Networks (MANETs) are widely preferred nowadays due to its ability to connect nodes without specific infrastructure which would be a boon to adverse communication devices. Most researchers work is hard to suggest efficient multipath routing protocols. The proposed work is extended from interference-aware expected transmission time routing (IAEETR) with multipath routing. This paper proposes a standard multipath routing protocol named Energy Efficient Quality of Service Routing Scheme to Predict Interference-Multipath Routing Protocol (EEQRPI-MRP) to attain better quality of service in terms of: energy consumption, packet delivery ratio, packet drop, end to end delay and throughput. The proposed multipath routing protocol is compared with other existing protocols such as: Ad-hoc On Demand Distance Vector (AODV), Near Optimal Radio Interference Aware Multipath routing Protocol (NICE-MRP), Efficient Stable Disjoint Multipath Routing Protocol (ESDMR) and Interference Aware Expected Transmission Time Routing (IAEETR). The efficiency of the proposed protocol is evaluated using NS2 simulator. The result shows 58% improvement in predicting optimized routing path and 65% improvement in interference avoidance compared to existing approaches.

Keywords: Radio interference, Multipath routing protocol, Mobile ad-hoc networks, Quality of service

1 Introduction

In general, Ad-hoc named from a Latin phrase which denotes ‘for this’. Ad-hoc networks are opted mainly for military regime, disaster rescue mission and for commercial travel agencies [1, 8]. MANETs are quite different in their operation compared to infrastructure based wireless communication networks [14]. Cellular network and Wireless Local Area Network (WLAN) falls under the above mentioned category which needs guidance of an Access Point (AP) to interact between source and destination nodes [2-3]. The main disadvantage of such network is the inability of communication nodes to interact at access point failures and the expensive cost it takes to install respective access points [7]. These drawbacks are avoided in MANETs as the individual communication nodes connect to other nodes without the use of common access points and nest their own network [15]. The built in transceivers of ad hoc network nodes give them inherent ability to create their own network in its transmission range [4, 16]. Ad-hoc networks follow a unique method to distribute messages between nodes without the help of access points [11-12]. Routing protocols gain their importance in order to properly use the available resources without interference and to establish co-operation among the nodes [5-6, 17, 23]. The routing protocols can be: single or multi-path, reactive (on demand) or proactive (table driven) and source or hop to hop [9, 13, 15, 18, 20]. Multi-path routing protocols are greatly preferred as it suppresses duplicate route requests (RREQs) at neighbouring nodes by using node and link disjoints [10, 19, 21-22]. The main objective of this research work is to propose a Quality of Service (QoS) based multi-path routing protocol named EEQRPI-MRP to avoid link interference and to reduce energy consumption through bandwidth improvement for MANETs. The NS-2 simulator is used to evaluate the performance and efficiency of the proposed protocol in realistic contexts including various metrics. This paper is organized as follows: Section II surveys certain existing routing protocol for MANETs such as: Ad-hoc On Demand Distance Vector (AODV), Near Optimal Radio Interference Aware Multipath routing Protocol (NICE-MRP), Efficient Stable Disjoint Multipath Routing Protocol (ESDMR) and Interference Aware Expected Transmission Time Routing (IAEETR). Section III proposes multipath routing protocol named Energy Efficient Quality of Service Routing Scheme to Predict Interference (EEQRPI-MRP). Section IV explains about the performance metrics opted for evaluation of the proposed multipath routing protocol, followed by

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simulation results and comparison in section V and conclusion in section VI.

2 Literature Survey

Several researchers proposed variety of multipath routing protocol for effective deployment of network resources. Charles Perkins and Royer proposed table driven Ad-hoc On Demand Distance Vector (AODV) routing protocol that creates, maintain forward and backward routes only on demand [1]. The AODV protocol uses the same route discovery procedure as that of dynamic Source Routing (DSR). Marina and Das modified the AODV protocol by using multiple node and link disjoint paths by using advertised hop count procedure. This gave rise to a new multipath routing protocol named Ad-hoc On Demand Multipath Distance Vector (AOMDV). Shin et al [6] extended the AOMDV protocol to concentrate on congestion control and proposed Adaptive Ad-hoc On Demand Multipath Distance Vector (A^2AOMDV). Abdou et al [2] implemented this virtue and proposed Non-interfering Coverage Area Multipath Routing Protocol (NICE-MRP). The specialty of NICE-MRP is its computational ability to find optimal and sub-optimal paths so as to draw two routing tables which would be easier to adapt topology changes. However, NICE-MRP doesn't guarantee proper end to end delay between nodes. This drawback was overcome by Interference Aware Expected Transmission time Routing (IAEETR) proposed Deng et al [11]. Alwadiyeh & Ala'FA [7] narrowed down the research on routing protocol to predict minimal interference path. They proposed two different multipath routing protocols such as: Efficient, Stable, Disjoint Multipath Routing Protocol (ESDMR) and Disjoint Multipath Routing Protocol (EDMR). These extensive surveys triggered the need for proposing a standard multipath routing protocol named EEQRPI-MRP to attain better quality of service in terms of: energy consumption, packet delivery ratio, packet drop, end to end delay and throughput. This proposed on-demand protocol consumes less energy and predicts link interference thereby attaining better quality of service.

3 Proposed Energy Efficient Quality of Service Routing Scheme to Predict Interference-Multipath Routing Protocol (EEQRPI-MRP)

The proposed EEQRPI-MRP is a proactive (table driven), multi-path and source routed. Unlike NICE-MRP protocol, the proposed EEQRPI-MRP uses hello packets and certain modifications are performed in the basic packet structure of AODV routing protocol. The radio interference across disjoint nodes is evicted by considering link expiration and path expiration time. The architecture of EEQRPI-MRP mainly concentrates on route identification, agent advertisement, route discovery and recovery.

The lifetime of source, intermediate and destination nodes are taken into account. The architecture of EEQRPI-MRP is shown in Figure 1. The route discovery mainly comprises of Route Request (RREQ) and Route Reply (RREP). The proposed RREQ message format includes link and path expiration time but not limited to lifetime of the source, intermediate and destination nodes. The proposed RREQ message format is shown in Figure 2.

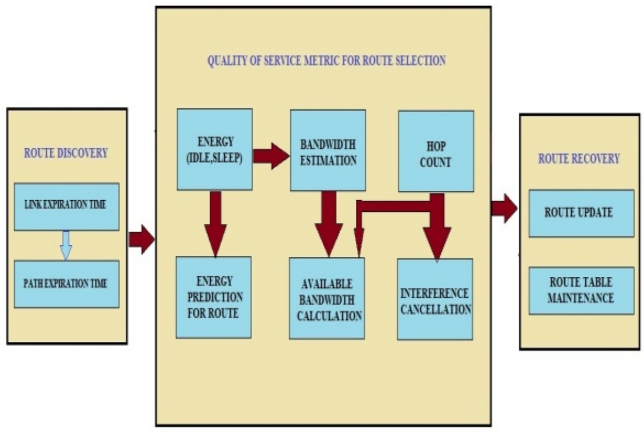

Figure 1. Architecture of proposed EEQRPI protocol

Type	J	G	Reserved	Hop count
RREQ ID				
Link Expiration Time	Path Expiration Time		Route Expiration time	Life time
Destination IP Address				
Destination Sequence Number				
Originator IP Address				
Originator Sequence Number				

Figure 2. RREQ message format of proposed EEQRPI protocol

The notations of the RREQ message format of proposed EEQRPI protocol is explained as follows: J represents the joint flag and it is reserved for multicast-type 1, G represents the gratuitous flag and it indicates whether the RREP should be cast to destination node denoted in the destination IP address field. When the reserved field is sent as '0', it is ignored on the node reception. Hop count represent the number of hops from originator IP address to the node handling the request. RREQID represents a sequence number in combination with originator IP address. Destination IP address represents IP address of the destination for which a route is desired. Destination sequence number represents the latest sequence number received in the past by the originator for any route towards the destination. Originator IP address represents the IP address of the node which originated the Route Request. Originator sequence number represents the current sequence number to be used in the route entry pointing towards the originator of the route request. The time in milliseconds for which nodes receiving the RREP considers the route to be valid is termed as lifetime. The RREP message format is followed as such that of AOMDV protocol and is shown in Figure 3.

Type	R	A	Reserved	Prefix size	Hop count
Destination IP Address					
Destination Sequence Number					
Originator IP Address					
Lifetime					

Figure 3. RREP message format of proposed EEQRPI protocol

Since the proposed multipath routing is table driven, the packet format for updating table information is to be maintained. The packet format of routing table comprises of source ID, destination ID, hop count, data forwarding status, expiration time, life time and forward check sequence number. The routing table for the proposed EEQRPI routing protocol is shown in Figure 4.

Source ID	Destination ID	Hop Count	Data forwarding status	Expiration time	Life time	Forward check sequence number

Figure 4. Routing table packet format of proposed EEQRPI protocol

The proposed EEQRI-MRP is postulated step by step as shown below:

Step 1: *Generate a Dynamic Node = N;*
Step 2: *Fix Routing Protocol = EEQRPI; // for Dynamic Routing*
Step 3: *Set of (N) ={Sa, Sb, S, ... Sn}*
Step 4: *Assume Sender Id = Ns;*
Step 5: *Assume Destination Id = Nd;*
Step 6: *Set Transmission Range = 250 m;*
Step 7: *Initialize MAC Protocol = 802.11;*
Step 8: *Assign Initial energy for node ETX = {Ns, Sa, Sb .... Sn, Nd}*
Step 9: *Assign the link expiration time (LET) = 0.5 ms*
Step 10: *Assign the Path Expiration time (PET) = 1ms*
Step 11: *Measure the stable route (Ns, Nd, ETx, LET, PET)*
Step 12: *If (Transmission range <= 250 && LET<= Threshold)*
Step 13: *Initialize the route discovery. Select the route path based link (LET)*
Step 14: *Increment the hop count based average energy path*
Step 15: *If (hopcount != Nd && PET, Threshold value)*
Step 16: *Update routing table for next hop selection on neighbour node*
Step 17: *Compare energy of each node for prediction optimized path.*
Step 18: *If (LET > Threshold value && PET > Threshold value)*
Step 19: *Discard routing path and update the routing table.*
Step 20: *End route selection.*

The broadcast window of the NS2 simulator with the proposed EEQRPI algorithm sending 'HELLO' message to establish connection between 1-hop and 2-hop adjoining mobile nodes is shown in Figure 5. Figure 5 also illustrates the expanded view of the source and sink nodes in a given coverage area.

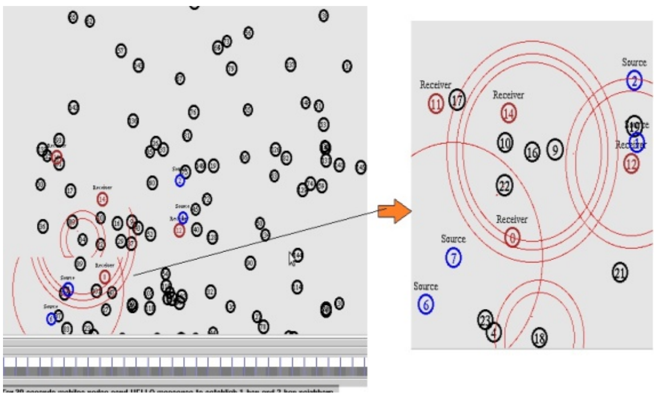

Figure 5. Broadcast window showing proposed EEQRPI scenario

4 Simulation Results

The efficiency of the proposed protocol is evaluated using NS2 simulator. The simulated network contains about 150 nodes with a transmission range limited to about 250 meters. The terrain size selected for the movement of the nodes is about 1200 m x 1200 m area for the total duration of 300 seconds. The CBR (Constant Bit Rate) stream traffic type is modeled with a data rate of four packets per second. TCP protocol is selected with a radio frequency of 2.4 x 10^9 Hz and 1 MBPS bandwidth. IEEE 802.11 is taken as the Medium Access Control (MAC) type with an individual packet size of about 512 bytes.

The initial energy allotted is 100 Joules which includes 0.9W transmit power and 0.4W receive power. Three RREQ tries are allowed for a stipulated HELLO interval of 1000 milliseconds. The table illustrating the detailed simulation metrics is shown in Table 1.

Table 1. Simulation parameters to evaluate the proposed routing protocol

Simulation Parameter	Value
Simulator	Ns-allinone-2.35
Terrain size	1200X1200 m
Number of Nodes	25,50,75,100,125,150
Transport Protocol	TCP
Radio Frequency	2.4e9Hz
Transmission range	250 m
Bandwidth	1 Mbps
Traffic type	CBR
Initial Energy	100 Joules
Propagation Model	Two ray ground
MAC type	802.11
Packet size	512 bytes
Speed	3 m/s
Transmit Power	0.9 W
Receive Power	0.4 W
Number of RREQ tries	3
HELLO Interval	1000 milliseconds
Allowed Hello loss	2
Simulation Time	300s

The proposed EEQRPI multipath routing protocol is to be evaluated to find its efficiency when compared to other existing routing methodologies. The following parameters act as a benchmark to evaluate the proposed methodology. The parameters are briefly discussed in this section.

Packet delivery ratio. The ratio obtained by calculating the total number of packets received at target node to the total number of packets sent off by originating or source node is termed as packet delivery ratio. This parameter reviews the reliability of the routing protocols and the transmission ability of the nodes. The expression for packet delivery ratio (PDR) is given by

$$PDR = (\text{Packet received} / \text{packet sent}) * 100\% \quad \textbf{(1)}$$

Packets dropped. This parameter indicates the number of packets which are lost during their journey from source to sink. There are "n" number of reasons for this event such as: the transmission ability of the nodes, source and node lifetime, improper routing, signal strength etc.

End to end delay. This represent the transmission time that an individual packet takes. This delay is calculated at the start of transmission of packets from upper layer of the source node and ends after successful reception of packets at destination. The End to End delay also includes the route discovery time, buffering time, reordering time and successful acknowledgement receiving time.

Routing overhead. This represent the total number of packets produced and sent by the routing protocol to carry out its significant purpose such as route request, route reply and route error. In other words, it is the total number of routing packets that are generated and transmitted during the stipulated network simulation time.

Throughput. The ratio obtained by calculating the total number of packets received at target node to the total transmission time is termed as throughput. In other words, it is the rate of packets that are received at the sink node per second.

Energy consumption. The value obtained by calculating the total amount of energy consumed by all the nodes at various network layers due to various actions such as send, receive and drop during the entire simulation time is termed as energy consumption.

Table 2 shows the packet delivery ratio comparative analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR. The PDR of the proposed EEQRPI-MRP shows about 5% increase for 150 nodes compared to that of the standard AODV and ESDMR protocols. This enhancement is made possible through appropriate RREQ and RREP intervals. The graph showing the packet delivery ratio analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR is shown in Figure 6.

Table 2. Simulation result showing PDR of proposed and existing multipath routing protocols

No of Node	AODV	NICE-MRP	ESDMR	IAEETR	EEQRPI
25	89	89	90	90	93
50	84	86	87	89	91
75	79	82	84	87	90
100	76	80	82	85	88
125	74	78	80	84	86
150	72	76	79	82	85

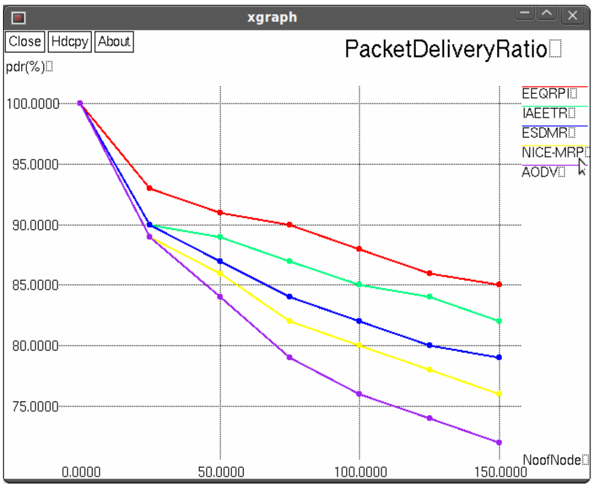

Figure 6. Graph showing PDR of proposed and existing multipath routing protocols

Table 3 shows the end to end delay comparative analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR. The end to end delay of the proposed EEQRPI-MRP shows about 43% decrease compared to that of the AODV and 25% decrease compared to that of IAEETR protocols due to less interference inherent signal strength. The graph showing the end to end analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR is shown in Figure 7.

Table 3. Simulation result showing end to end delay of proposed and existing multipath routing protocols

No of Node	AODV	NICE-MRP	ESDMR	IAEETR	EEQRPI
25	1.09	1.05	0.87	0.83	0.62
50	1.29	1.25	0.98	0.96	0.73
75	1.53	1.41	1.16	1.09	0.94
100	1.64	1.57	1.32	1.26	1.12
125	1.75	1.7	1.47	1.41	1.35
150	1.96	1.89	1.68	1.53	1.46

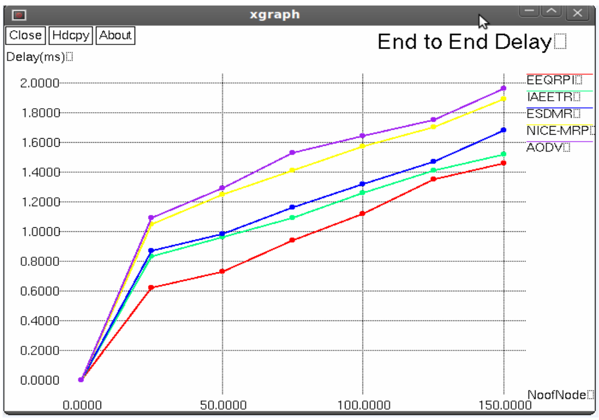

Figure 7. Graph showing end to end delay of proposed and existing multipath routing protocols

Table 4 shows packets dropped comparative analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR.

Table 4. Simulation result showing packets dropped by proposed and existing multipath routing protocols

No of Node	AODV	NICE-MRP	ESDMR	IAEETR	EEQRPI
25	93	81	68	58	42
50	168	102	91	64	59
75	182	149	124	93	86
100	226	192	165	125	97
125	251	225	198	148	106
150	279	264	221	178	115

The packets dropped by the proposed EEQRPI-MRP shows about 53% decrease compared to that of the AODV and 48% decrease compared to that of NICE-MRP protocols due to the addition of link and path expiration time in route discovery.

The graph showing the packets dropped by the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR is shown in Figure 8.

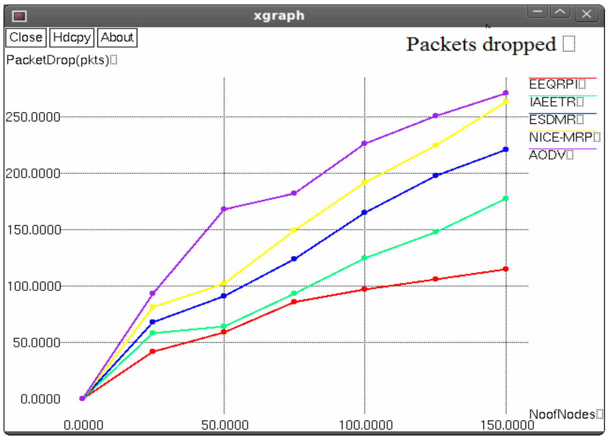

Figure 8. Graph showing packets dropped by proposed and existing multipath routing protocols

Table 5 shows throughput analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR. The throughput of the proposed EEQRPI-MRP shows about 12% increase compared to that of the AODV for 150 nodes and 21% increase compared to that of NICE-MRP for 100 nodes due to increase in network lifetime and interference avoidance.

Table 5. Simulation result showing throughput of proposed and existing multipath routing protocols

No of Node	AODV	NICE-MRP	ESDMR	IAEETR	EEQRPI
25	1047	1167	1204	1217	1254
50	2247	2375	2414	2479	2654
75	3690	3427	3674	3984	4168
100	5407	5541	5617	5871	6574
125	6627	6714	6746	6842	7297
150	8124	8249	8421	8684	9124

The graph showing the comparison of throughput by the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR is shown in Figure 9.

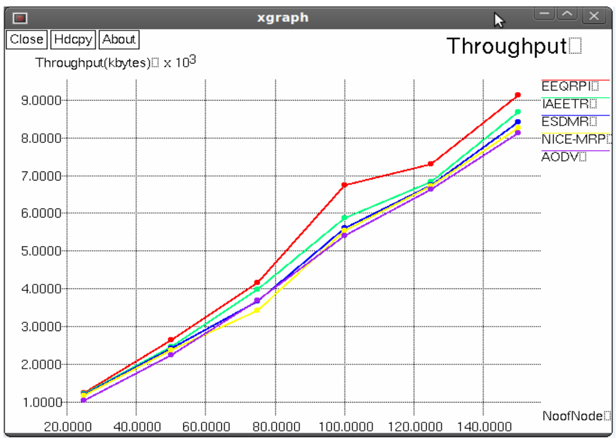

Figure 9. Graph showing throughput of proposed and existing multipath routing protocols

Table 6 shows energy consumption analysis of the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR. The energy consumed by the proposed EEQRPI-MRP shows about 47% decrease compared to that of the AODV for 150 nodes and 34% decrease compared to that of ESDMR for 150 nodes due to proper routing which is rendered by periodic updation of routing tables.

Table 6. Simulation Result Energy Consumed by Proposed and Existing

No of Node	AODV	NICE-MRP	ESDMR	IAEETR	EEQRPI
25	9	8.5	7	6	3.5
50	17	15	12.5	9	5.5
75	20.5	19	18.3	14	10
100	26.5	24.8	21.5	18	12.5
125	32.3	31	26	22.5	15.8
150	35.5	33	29	27.4	19

The decrease in energy consumption is achieved also due to the stringent selection of routing path that consumes less energy. The graph showing the comparison of energy consumption by the proposed EEQRPI-MRP routing protocol with other existing routing protocols such as AODV, NICE-MRP, ESDMR and IAEETR is shown in Figure 10.

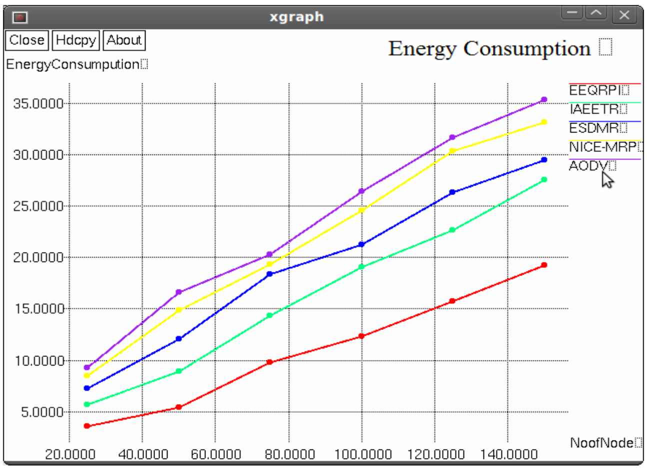

Figure 10. Graph showing energy consumed by proposed and existing multipath routing protocols

5 Conclusion and Future Work

In this paper, a typical multipath routing protocol is proposed named Energy Efficient Quality of Service Routing Scheme to Predict Interference-Multipath Routing Protocol (EEQRPI-MRP) to attain better quality of service in terms of: energy consumption, packet delivery ratio, packet drop, end to end delay and throughput. Extensive surveys are performed considering other existing routing protocols such as: AODV, NICE-MRP, ESDMR and IAEETR. Simulations are performed using Network Simulator 2.35 with metrics indicated in Table 1. This paper has achieved its target by avoiding interference among nodes in MANETs by performing variations in the RREQ and RREP packet structure. Energy consumption in nodes is also reduced by using independent route discovery and route recovery aspects.

The simulated result shows 43% and 25% decrease in end to end delay compared to that of the AODV and IAEETR protocols respectively. It is also evident that packets dropped by the proposed EEQRPI-MRP are decreased by 53% and 48% compared to AODV and NICE-MRP protocols respectively. The simulated results indicate 5% increase in packet delivery ratio for 150 nodes compared to that of the standard AODV and ESDMR protocols. Throughput of the proposed multipath routing protocol shows 12% and 21% increase for 150 nodes compared to AODV and NICE-MRP protocols. Major contribution of the proposed protocol paves way to 47% and 34% decrease in energy consumption compared to AODV and ESDMR for 150 nodes. The future work will narrow down towards femtocell deployment in MANETs implementing the proposed EEQRPI-MRP protocol. Future insights also include collision avoidance and creating real time networks with better link quality and endurance.

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