Route Constancy and Energy Aware Routing Protocol for MANET

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Summary
In Mobile Ad-Hoc Networks (MANETs) consists of nodes which are powered by batteries with temporary power supplies. Because of faults in nodes links are prone to disconnection due to frequent battery drain or the mobility of the node beyond the coverage area of the signal. Because of these reasons a routing protocol that optimises the battery usage and route stability is very important. Based on this motivation we present here an Route Constancy and Energy Aware Routing Protocol (RCEARP) to improve the network sustainability, packet delivery and to minimise the network routing overhead. Routes with more residual energy and stable links are selected by RCEARP. The comparative analysis of RCEARP with AODV and Link Stability and Energy Aware routing protocol (LSEA) revealed that the proposed protocol RCEARP improves the network lifetime by 10% to 13% and achieves 6% – 11% more packet delivery ratio compared to AODV and LSEA. RCEARP has also accomplished better performance in term of routing overhead, which is reduced by 38% and 22% as compared to AODV and LSEA respectively.

Key words:
MANET, Reliable Routing, Residual Energy, Network Lifetime, Route Stability, Energy Aware

1. Introduction

Since all the nodes in MANET are movable and powered by short-lived batteries [1], therefore repeated link ruptures in MANETs are mostly caused by faulty nodes to the diminution in energy and frequent movements of nodes towards the out of coverage areas where signal strength is very weak. A node constantly loses its energy due to its frequent mobility and which results in frequent route discontinuation. A number of strategies have been proposed to improve the network life by stabilising the node resources including the energy [2], [3], [4], [5], [6]. Energy consumoption of network nodes can be effectively minimised by carefully selecting the route between source and destination nodes [7], [8], [9]. Furthermore, it is equally important to avoid selecting the weak and fragile routes while preserving the energy of the node on priority. Hence, it can be concluded that both energy preservation and stable routes are important in the design of an efficient routing protocol for MANET. Here we propose a routing protocol that considers both node-energy and route constancy as important parameters while selecting the optimal route from source to destination. The proposed scheme "Route Constancy and Energy Aware Routing Protocol for MANET" guarantees the selection of optimal route for data transmission from source node to destination by taking into account both route-stability and node-energy.

2. Related Work

The motivation behind the energy sensible routing protocol is to improve the network life by minimising the consumption of power by the node. Network lifetime is always taken as the point of interest for the design and deployment of a MANET routing protocol [12]. Several novel and interesting ideas have been proposed in the past decade that emphasise the minimisation of the power consumed by a mobile node. Many of these protocols which are based on energy aware routing utilise energy centric routing metric in place of hop-count metric [13]. A review of important energy aware routing protocols is presented in this section.

The MBCR protocol presented in [14] claims energy efficient routing in MANET by calculating residual energy of the node. The cost of routing in this scheme is calculated as a function of residual battery capacity of the communicating node. The destination node aims to find the optimal path that minimalizes the total routing cost of all realistic paths. Mathematically, the selected path in this protocol is

$$\min \sum \frac{1}{R_i} \text{ for node } i \in \text{path} \quad (1)$$

Where R_i shows the residual node energy i. Thus the network lifetime could be increased in MBCR it is however important to note that the route selected by MBCR has the minimum of the submission of routing cost of each route, therefore, some of the nodes with less residual energy may still be designated for the optimal route.

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Min-Max Battery Cost Routing (MMBCR) is an alternative scheme that improves MBCR by using similar routing cost with a unique mechanism of selecting path by avoiding nodes with less residual energy [15]. Mathematically,

$$\min \max \left\{\frac{1}{R_i}\right\} \text{ for node } i \in \text{path} \quad (2)$$

The MTPR - Minimum Total Transmission Power Routing scheme [16] finds the optimal route which requires less power to consume by considering the general route $R_d = N_s, N_1, N_2 \dots N_d$ where N_s and N_d are source and destination nodes respectively. The transmission power between two communicating nodes N_i and N_j is calculated with function $T_p(N_i, N_j)$. For an optimal route the total power consumption is

$$P(R_d) = \sum_{i=0}^{d-1} Tp\ (N_i, N_{i+1}) \text{ for all nodes } N_i \in R_d \quad (3)$$

The best route R_o must satisfy

$$P(R_o) = \min_{R_j \in R_*} P(R_j)$$

Where R_* represents the set of all likely routes. Because MTPR does not take into account the remaining node power that is why it is more likely that it will fail in prolonging the lifespan of each individual host.

C.K Toh et al. presented Conditional Max-Min Battery Capacity Routing (CMMBCR) which is a hybrid approach for finding the optimal route [15]. They combined the functionality of MTPR with MMBCR in such a way that both the residual energy of nodes and total transmission power consumption of routes were considered. The optimal route with minimum transmission power is selected when all the nodes in the feasible path have more residual energy than the threshold ‘γ’. MMBCR scheme may be applied to increase the lifespan of the mobile nodes if the nodes do not have greater residual energy as compared to the threshold ‘γ’. The threshold value in CMMBCR plays vital role in enhancing the network lifespan and improving the consumption of transmission power by selecting a suitable threshold value.

An energy efficient routing protocol PS-AODV proposed in [17] takes routing decision on the basis of load situation of the communicating node. The node first verifies its current load prior to forwarding the RREQ packet to rest of the neighbouring nodes. It simply discards RREQ packet if the load of the node is extremely high. The forthcoming RREQ packets are again forwarded if the load of the node is reduced.

The Energy-Aware AODV (EAODV) by Zhaoxiao et al. [18], which is primarily based on AODV utilises the backup routing technique. This scheme essentially selects the route based on the dynamic priority-weight(β_i (t)). The calculation of dynamic priority-weight is done by equation 4.

$$\beta_i\ (t) = \left(\frac{R_i(t)}{C_i(t)}\right)^2 \quad (4)$$

$R_i(t)$ and $C_i(t)$ represents the residual and consumed battery energy of node n_i at time ‘t’ respectively. The optimal route R_o is the one which verifies the following condition

$$R_o = \max_{route_i \in r_*} (\beta_i)$$

Where r* Contains all the possible routes.

Link Stability and Energy Aware (LSEA) routing protocol is also an important variation of standard AODV protocol [19]. The link life and the residual energy of the node is taken into account in the route discovery process of LSEA while searching for a route towards the destination. LSEA proposed some changes in the route discovery of AODV and select only those nodes to rebroadcast the RREQ packet, which satisfies the constraint value of link life time and residual energy of the node. The previously proposed method in [20] is used in LISA to calculate the lifespan of link, Global Positioning System (GPS) is used to gather the information in this protocol.

3. The Proposed Route Constancy and Energy Aware Routing Protocol

The proposed scheme RCEARP is a routing protocol that is in vogue as it initiates a route discovery process when there is a requirement. The main focus of the proposed scheme is to design a stable route that is consist of nodes having highest available battery power and have longer network life.

3.1 Preliminaries

Following section discusses the significant parameters used in the paper. However, the process of route discovery of the proposed protocol is elaborated in the following sections of the paper.

- **Energy Sensible RREQ Packet Format (ES-RREQ):** AODV routing request packet (RREQ) entries are referred as an Energy Sensible Route Request (ES-RREQ) and they have been extended as well as per the requirements of our proposed scheme,.Figure-2. The additional 5 fields of the ES-RREQ packet are

- o ***XPos, YPos:*** which contains the (X, Y) coordinates of the mobile node
- o ***Speed:*** which is the current speed of the mobile node
- o ***Direction:*** which is the direction or angle of the mobile node
- o ***LET:*** which contains the link Expiration Time between the sender and receiver of this ES-RREQ.

...	XPos	YPos	Speed	Direction	LET

Figure 2: ES-RREQ Message Format

Reliability Factor (RF): RF [21] chooses only the those routes which have large route expiration time but have less number of Hops; which makes these routes reliable or stable route for transferring data between source and destination. RF is basically a difference of normalized values of Route Expiration Time (RET) and Hop Count (HC), which is calculated using equation (5).

$$RF = \frac{RET}{MaxRET} - \frac{HC}{MaxHC} \quad (5)$$

Route Expiration Time (RET): The Route Expiration Time (RET) is described as the minimum Link Expiration Time (LET) for the whole achievable route between the source node and the destination node, where LET signifies the time it takes for two node to keep in contact [20, 22].

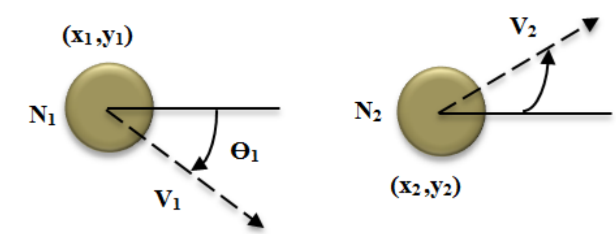

Figure 3: Link Expiration Time

The LET represents the length of time for which two mobile neighbouring nodes will remain in contact; the calculation of LET can be described for two communicating nodes N_1 and N_2 having same transmission range "r". Let (x_1, y_1) and (x_2, y_2) be the x–y coordinates for nodes N_1 and N_2 respectively cf. Figure-3. As illustrated in [20] nodes N_1 and N_2 move at speeds of v_1 and v_2 at angles θ_1 and θ_2 respectively. Then the LET between nodes N_1 and N_2 is calculated using equation (6).

$$LET = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \quad (6)$$

$$a = v_1 \cos\theta_1 - v_2 \cos\theta_2$$

$$b = x_1 - x_2$$

$$c = v_1 \sin\theta_1 - v_2 \sin\theta_2$$

$$d = y_1 - y_2$$

Hence, the RET is the lowest LET of all the viable routes of the network, calculated using equation (7).

$$RET = Min\ (LET_1, LET_2, LET_3, \ldots, LET_n) \quad (7)$$

Hop Count (HC):It is the number of hops which are involved in the viable path between source and destination. MaxRET:The MaxRET is the maximum RET of all viable routes whichare available at the destination node, calculated using equation (8)

$$MaxRET = Max\ (RET_1, RET_2, RET_3, \ldots, RET_n) \quad (8)$$

MaxHC : The MaxHC is the maximum Hop Count of all viable routes between source and destination, calculated using equation (9)

$$MaxHC = Max\ (HC_1, HC_2, HC_3, \ldots, HC_n) \quad (9)$$

4. Route Discovery Process of RCEARP Protocol

The route discovery in the RCEARP protocol starts when source and destination nodes try to communicate and the source node does not find the routing entry for the destination node in its routing table. The route discovery process starts by first broadcasting the route request (ES-RREQ) message to all active nodes in the neighbour. The ES-RREQ packet is an extension of the AODV RREQ packet, which is shown in Figure (2).

Maintaining the equilibrium in the utilisation of energy among the movable nodes and selection of highly stable routes are the main objectives of RCEARP protocol, which in turn improves the network lifespan. The route request forward decision should be based on the Residual Energy (RE) of each node for balancing the utilisation of the node energy. For this purpose, we introduce the idea of delay-forwarding.

The delay-forwarding procedure is such that when ES-RREQ packet is received by an intermediate node having no route to the destination in its routing table, then node holds the ES-RREQ packet for some period of time called Holding Time (HT) of this packet, which is calculated using equation (10).

$$HT_{ES-RREQ_i} = 1/\varrho_i \quad (10)$$

Where,

ϱ_i *is the Residual Energy of node i*

$HT_{ES-RREQ_i}$ *is the Holding Time of ES − RREQ packet at node i*

The holding time of ES-RREQ at each node is related to its current residual energy which is found to be inversely proportional to the holding time of the intermediate node. Higher level of remaining energy of a node will result in smaller holding time and vice-versa. A node after receiving and accepting the packet of route request neglects all the similar requests later on. The ES-RREQ packet broadcasted to neighbouring nodes before the nodes, which have the higher residual energy, based on the idea of delay-forwarding. The nodes with less residual energy will have to wait for longer duration of time and thus broadcast the ES-RREQ packet after a significant delay therefore there are more chances of rejecting the request packets from such nodes. In the meantime, the midway nodes before forwarding the ES-RREQ packet, calculates Link Expiration Time (LET) between the current node and ES-RREQ sending node according to Equation (6).

The minimum LET is selected by midway nodes and finally, after the expiration of holding timer, they increment the hop count and broadcast the ES-RREQ message to the neighbouring nodes. This has been clearly explained in Figure-3. From many neighbouring nodes more than one copy of same ES-RREQ may be received at midway nodes which are consequently discarded. If the intermediate node has an active to the destination node it send back the route reply packet to the source node and eventually a stable route is selected. The next section explains the complete procedure of stable route selection.

5. Route Selection of RCEARP at Destination Node

When first ES-RREQ reaches to the destination node that is D, it results in the start of timer which collects all the rest of ES-RREQ packets to the destination. As the process takes place, when the timer expires, Reliability Factor (RF) [21] is applied to each already collected route from source to destination and selects the higher RF Value route.

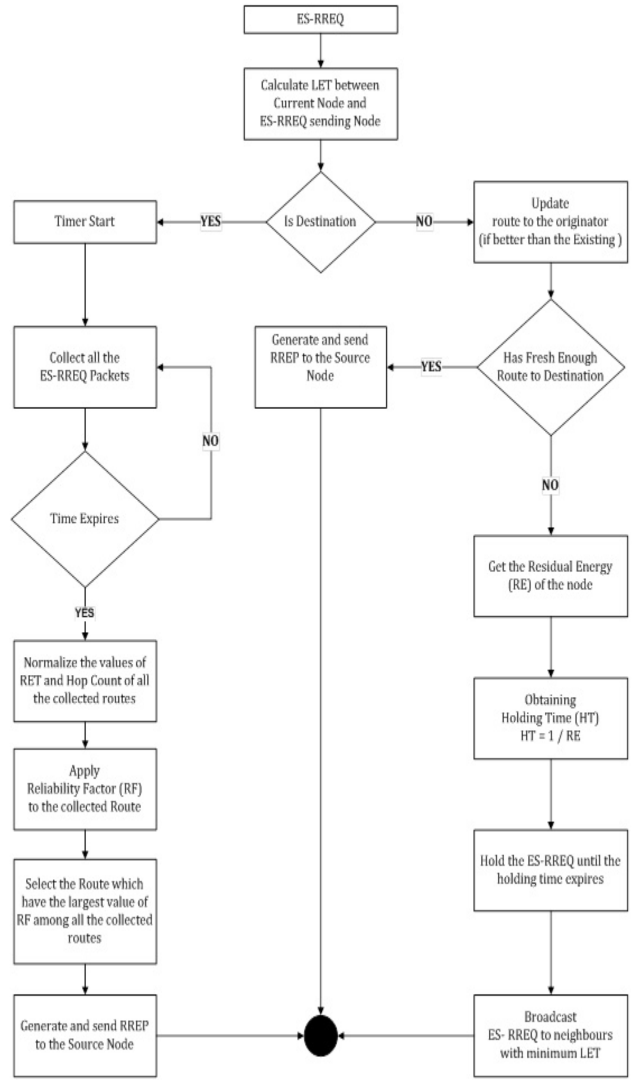

Figure 1: Flow Chart of Route Discovery Process of RCEARP

6. Performance Evaluation

Using Network Simulator (NS-2.35) [23] , simulations were carried out to evaluate RCEARP Protocol. The employed model was Random Waypoint Mobility model where each node selects initial point randomly and then waits for the pause time. Each node moves to a random destination with the chosen velocity between the maximum and minimum velocities. As it reaches to the destination, it again waits for the pause time and then further moves towards any new random destination with again different speed. Every node repeats the same cycle as mentioned above independently until the time that simulation stops.

Table 1: Simulation Parameters of Experiment: Effect of Nodes Speed

Parameters	Value
Protocols	RCEARP, AODV and LSEA
No of Nodes	50
Simulation Area	1000m X 1000m
Mobility Model	Random Waypoint
Traffic Type	Constant Bit Rate (CBR)
Queue Length	50
Transmission Range	250m
Propagation Model	Two Ray Ground
Simulation Time	300 s
Nodes Speed	5, 15, 25, 35, 45 ms^{-1}
Initial Energy	10 J
Receiving Power	31.32e-3 W
Transmitting Power	35.28e-3 W

All the parameters which have been employed in the simulation effect of various node are mentioned in Table1. Around 50 nodes have been used in the simulation of the proposed scheme in the area of 1000m X 1000m. This offers an abundant space for the node movement and to look for any new discovered route. The simulation is set to 25 connections on maximum. Traffic sources are set to continuous bit rate (CBR). The pairs of source-destination are randomly spread over the network. With the rate of 2Mb/s and a nominal range of 250 m, 512-byte data packets are used. Moreover, a zero pause time is used for the mobility simulation level along with the nodes that are in constant movement in simulation area. An average of multiple runs with various seed values that are used for the traffic models is represented by every node.

Experiment: Effect of Nodes Speed on RCEARP
In 5o nodes network, the speed varied from 5ms^{-1} to 45ms^{-1} to evaluate the different speed effect on the proposed routing scheme. Table -1 shows the simulation parameters of the experiment.

7. Performance Metrics

Following are metrics used in the experiment to evaluate the protocols.
Network Life Time: The time taken until all nodes die out due to the battery exhaustion.
Energy Consumption: It is defined as the proportion between the total energy that is utilized in the network to the total number of nodes used.
Packet Delivery Ratio: it is ratio that is calculated by the number of data packages which are received by the destinations with those sent by sources.
Normalized Routing Load: It is the number of routing packets transmitted per data packet delivered at the destination.
Throughput: The amount of data received by the destinations per unit time is referred as throughput of the network. Normally, it is measured in bits/sec.
Routing Packets: The total number of routing packets involved in the network.
Received Packets: Received packets represent the total number of data packets received at the destination.

8. Simulation Results and Discussion

The performance of the proposed protocol in this paper is evaluated by comparing it with traditional AODV and recently proposed Link Stability and Energy Aware (LSEA) routing protocol.

Figure-4 shows the plot of network lifespan where it can be seen that RCEARP improves the network lifetime from 9% - 10% over LSEA and between 11% - 13% over AODV. The main reason for this improvement is the novel route discovery and route selection technique of RCEARP. In the route discovery process the nodes with higher residual energy as compared to its neighbours is first allowed to broadcast a RREQ packet. This is because of the usefulness of prioritising the nodes with higher residual energy over the nodes which are expected to run out of battery power soon thereby improving the overall network lifespan. The selection technique of RCEARP by the destination node is also a very important factor for network lifetime improvement. Nodes with highest route expiration time with minimum number of hops in the route are selected by the destination node to make it highly stable and reliable. In contrast to standard AODV where a shortest possible path is selected without any other parameter taken into account the proposed protocol eliminates the routes with lowest expiration time. This technique of selecting the stable routes minimises the need of initiating the route maintenance process that contributes in saving the energy of the nodes and improving the network lifespan.

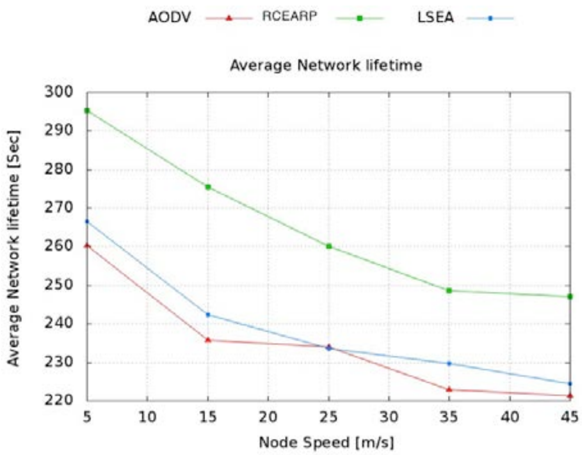

Figure 2: Average Network Lifetime vs. Node Speed

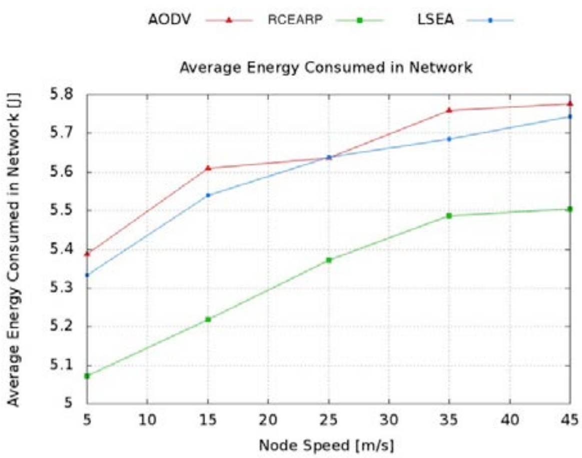

Figure 3: Average Energy Consumed vs. Node Speed

The impact of speed of node on the average level of energy consumption can be seen in Figure 5. It is observed that for all protocols (RCEARP, LSEA and AODV) the energy consumption and node speed increase in parallel, which is due to the increased node speed and more number of broken links. Such failures result the need of extra rout discovery, which requires more energy to consume. It is evident that RCEARP has better performance in term of required energy to consume as compared to LSEA and AODV. Selection of reliable routes consisting of reliable nodes and link with greater expiration time are the main factors in the unique design of RCEARP that provide these positive results. In fact in RCEARP failures of the route are reduced due to wiser selection of reliable routes. This drop in the route failures consequently results in significant decrease of route maintenance procedures, which lowers energy requirement and consumption of the nodes.

The benefit of the proposed protocol over other protocols in term of PDF, which is the ratio of the number of packets received by the destination node with those sent by the CBR sources, can be observed in Figure-6. It is also shown that the proposed protocol provides improved PDF than the rest of the protocols. The RCEARP increases the PDF from 4% to 6% over LSEA and from 8% to 11% over AODV. The main factors of such results are again the better selection of routes in RCEARP protocol with reliable and higher rout lifetime. Nodes with highest residual energy levels, good route lifespan and less number of hops are selected in RCEARP. In contrast, only shortest path is considered in AODV neglecting the residual energy of the nodes and the expiration time of link in the route discovery process. AODV simply broadcasts the RREQ packets as a result of which a shortest is route is selected regardless of the reliability or lifetime of the route.

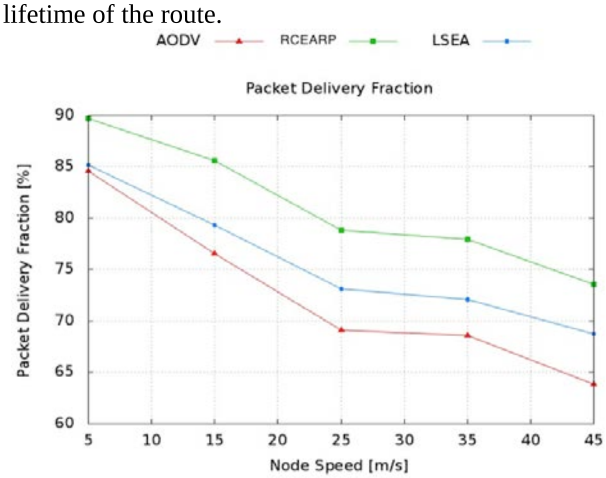

Figure 4: Packet Delivery Fraction vs. Node Speed

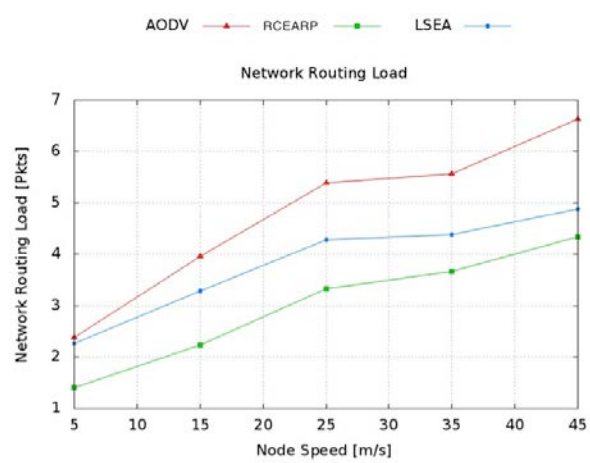

Figure 5: Network Routing Load vs. Node Speed

The impact of node speed on the performance of all three protocols in term of Network Routing Load (NRL) is shown in Figure-7. The Figure-7 also illustrates that NRL and the node speed increase in parallel for RCEARP, LSEA and AODV. The reason is the number of broken links due to increase in the node speed and the failure of RREQ packets to reach at the destination. Such failures cause extra requirement of route discovery mechanism that potentially improves the network routing overhead. Comparison shows that RCEARP outperforms other protocols in term of routing load. RCEARP on average reduces the overhead by 38% and 22% as compared to AODV and LSEA respectively. In RCEARP owing to reliable route selection, failures of the route are minimised, which eventually results in minimisation of route maintenance requirement, which in turn reduces the network routing load for route discovery and maintenance.

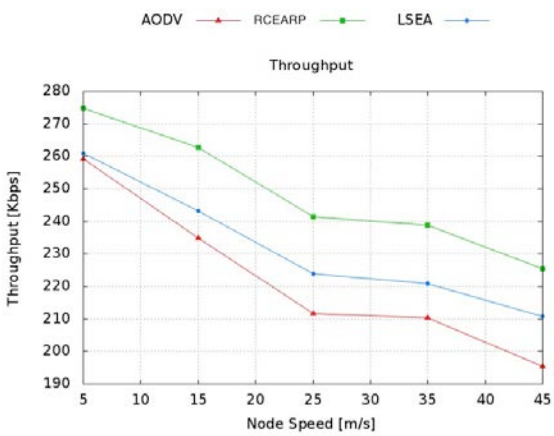

Figure 6: Throughput vs. Node Speed

The throughput, which is important metric for the measurement of network transmission ability, is also compared with different protocols as a function of variable speeds, as shown in Figure-8. It can be seen that with the increase in node speed there is gradual decrease in the throughput of the network. As all nodes are expected to be mobile in MANET that is why more expectations of link failure and requirements of establishing new routes are. The route rupture increases the demand of route-maintenance, which results in more rebroadcast requirements and increased consumption of bandwidth. Consequently the throughput decreases as soon as we increase the mobility of node at higher speeds. Figure-8 endorses the better performance of RCEARP over LSEA and AODV. Throughput of RCEARP is higher than LSEA and AODV by 13% and 7% respectively. Again the selection of reliable routes has significant contribution in better link lifetimes.

A comparison of the number of routing packets versus speed of the node is given in Figure-9. With the increase in node speed the number of routing packets increases for all types of protocols. However, it may be observed that the routing packets of RCEARP are lesser as compared to rest of the protocols, which is due to the consideration of reliability factor in route selection. Hence reducing the number of routing packets that contribute in the route maintenance and discovery process.

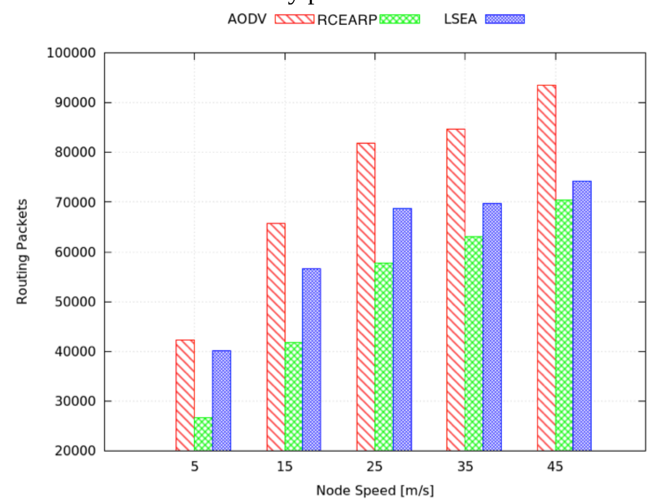

Figure 7: Routing Packets vs. Node Speed

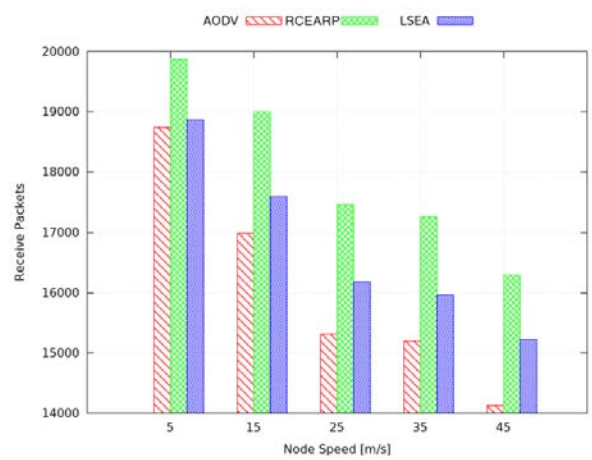

Figure 8: Receive Packets vs. Node Speed

Figure-10 presents the plot of received packets, which elaborates the benefit of RCEARP in term of received data packets at variable speeds. It can be seen for all the protocols that when the nodes move with higher speed the total number of received packets decreases because the routing paths are easily and frequently broken with the increase in mobility and speed. Hence a better performance of RCEARP has been observed against LSEA and AODV protocols. Because of the better route selection with emphasis on reliability and node-energy the number of packets received in the case of RCEARP is greater than others.

9. Conclusion

It has been concluded that MANETs are composed of the various groups of nodes having mobility and they are powered with the batteries which have temporary power supplies. This results in the frequent link breakages in MANETs resulted because of the node failure. The cause of the node failure is the shortage of energy and out of the transmission range movement. Furthermore, due to path disconnection, route maintenance or route discovery process had to be started in order to re-establish the broken path causing the extra consumption of energy nodes. Also it adversely affects the performance of the network. The aim of the paper is to present a protocol that works efficiently. The proposed model is Route Constancy and Energy Aware Routing Protocol which balances the energy utilization among the mobile nodes and selecting the highly stable routes which leads to the increase of network life and ultimately enhances its performance. Moreover, concept of delay-forwarding has been introduced in the model to bring the balance in energy consumption. The delay-forwarding concept basically processes as the request message is held for some duration of time which is referred as Holding Time (HT) before sending it further. The calculation of HT time is entirely based on the node residual energy. Through this technique, only those nodes which are high in residual energy will be selected among all the neighbour nodes. In addition, out of all the viable routes that are gathered at the destination node, only those routes are selected which have high reliability factor (RF) value. For the evaluation of the performance of the proposed protocol, Extensive NS-2 situation has been carried out. Furthermore, if ESRBSR with AODV and Link Stability and Energy Aware routing protocol (LSEA)are compared together ,then it can be seen by the results that the lifetime of the protocol ESRBSR is increased 10%- 13% and it also accomplishes higher packet delivery ratio upto 6%-11%. Another major difference is in terms of routing overhead reduction as RCEARP decreases the routing overhead by 22% as compared to LSEA and by 38% as compared to AODV.

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