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An Integrated Multiple Cell and Trust Based Progressive Energy Efficient Routing in Mobile Ad Hoc Network

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Abstract: In this research to minimize the energy consumption on broadcasting the message through multiple cells, Multiple Cell and Trust-based Progressive Energy Efficient Routing (MC-TPEER) framework is developed. MPEER protocol consists of the integration process where the energy consumption is minimized and trust maintenance is maximized. Initially, for minimizing the energy rate on multiple cell based broadcasting, MC-TPEER follows the shortest path routing scheme. Multiple cell-based progressive energy efficient routing model on movable node starts by searching of the entire shortest route path in mobile ad-hoc network and picks up the minimal energy conservation path. MC-TPEER was also implemented using NS2 and compared against anonymous location-based efficient routing protocol and report-based payment scheme to assess its performance experimentally. The trust level on broadcasting the message, packet delivery ratio is reported versus several variables where MC-TPEER showed to be superior when compared to the other methods.

Key words: Mobile ad hoc network, routing protocol, energy consumption, route discovery, NS2

INTRODUCTION

Mobile Ad Hoc Network is an intensifying field in the area of wireless communications. Anonymous Location-based Efficient Routing Protocol (ALERT) (Shen and Zhao, 2013) was designed with the objective of improving the routing efficiency through geographic routing mechanism. A secure payment scheme (Mohmoud and Shen, 2013) ensured less communication cost and overhead while performing message transmission. MANET provides sufficient flexibility in order to regulate the dynamic environment by auto re-configuration (Rao *et al*., 2011), capable of sustaining link status information for numerous devices. Optimization of energy consumption was the study (Li *et al*., 2015) using non-linear programming problem.

Cluster Based QoS Routing protocol (CBQR) for MANET (Suri *et al*., 2010) which not only deals with bandwidth requirement over the wireless network but also considers routing, storage overheads and limited battery power. Progressive energy efficient routing protocol (Jinhua and Xin, 2011) derived a new link cost model to more accurately track the energy consumption. This protocol achieved minimum routing overhead, path setup delay with reduced energy consumption compared to other protocols. Link stability and energy aware metric called LAER (De Rango *et al*., 2012) used greedy technique based on joint metric and modified perimeter forwarding strategy for the recovery from local maximum. This method attained better energy saving since routes are decided based on Greedy perimeter forwarding with energy and stability.

In RCBRP, route discovery is performed by inter-cluster on-demand and intra-cluster table-driven routing which increases only throughput but not other QoS parameters (Kumbharey *et al*., 2012). Energy efficient cluster based routing protocol (Hosseini *et al*., 2009) in which all member nodes, except cluster head and gateway nodes were in idle condition. Energy consumption was significantly reduced but reduction in packet delivery ratio was not concentrated. Cluster based service discovery architecture for MANET (Karunakaran and Thangaraj, 2011), cluster head selection is performed by assigning a combined weight value based on power level, connectivity and stability. This protocol achieved reduced delay and overhead, but did not concentrated on energy.

Type based cluster forming algorithm (Wu *et al*., 2010) with cluster formation stage and cluster update stage that employed the stability factor as the parameter to activate the cluster head election process as the convenient way to assign nodes of the same type into a single cluster within a certain geographic range. This achieved better QoS with reduction in number of cluster head update events and cluster change events. Energy and load based cluster head election algorithm (Savitha

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and Chandrasekar, 2012) transfer data from source to destination that selected nodes of high energy and low load for carrying out data transmission path. While transmitting data, the energy level of each node is considered and when there is any depletion of energy at intermediate node alternate path is chosen. However, the method did not give much importance for selecting Gateway nodes and the selection of nodes near to destination nodes.

Efficient energy utilization has become important for network operation since the accumulated effect of increased data rates may result in unsustainable requirements on energy consumption in wireless networks. Kolios *et al*. (2014), store and carry forward scheme was introduced with the objective of achieving the energy saving by using shortest route paths to the base station. In Vazifehdan *et al*. (2014), reliable minimum energy cost routing and reliable minimum energy routing were introduced aiming at improving the energy efficiency and therefore the network lifetime considerably. Energy efficient reprogramming using swarm was introduced by De *et al*. (2010) to improve the number of message transmissions being made. Energy efficient trajectory tracking was introduced by Bhattacharya *et al*. (2015) using situational bounding to maintain robustness and accuracy during message transmission. In Gong *et al*. (2010), polynomial time heuristic approach was introduced to guarantee timely transmission of data using reward-based scheduling.

One of the important issues in MANET is to provide stable routing. Energy efficient stable routing using fuzzy logic decision model was introduced by Palaniappan and Chellan (2015) aiming at improving the routing efficiency. Cluster-based routing protocol using network coding provided an insight into reducing the energy consumption and therefore improving the network lifetime. Another routing protocol was designed by Bosunia *et al*. (2015) to improve the reliability of data delivery in MANET.

Based on the aforementioned techniques and methods in the work, an efficient multiple cells and trust-based progressive energy efficient routing framework is designed with the objective of reducing the energy consumption on broadcasting the message and improving the trust level in MANET.

MATERIALS AND METHODS

Design of multiple cell and trust-based progressive energy efficient routing framework: The objective with respect to the multiple cell and trust-based progressive energy efficient routing framework is to minimize the energy consumption on broadcasting the message through multiple cells and design a trust based route discovery in MANET. Two methods multiple cell-based progressive energy efficient routing and trust-based route discovery are proposed to solve the energy minimization problem. Figure 1 shows the block diagram of multiple cell and trust-based progressive energy efficient routing framework.

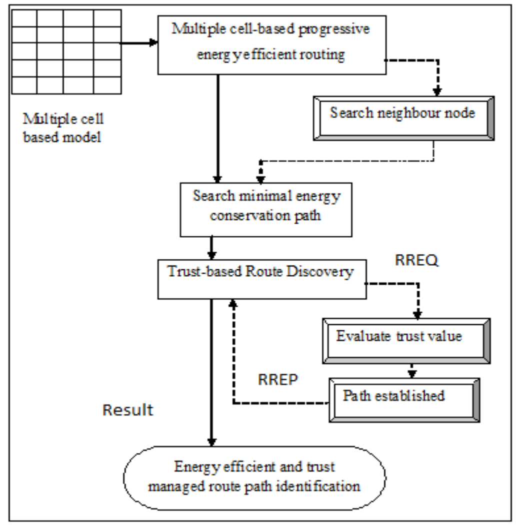

Fig. 1: Block diagram of multiple cell and trust-based progressive energy efficient routing framework

As shown in Fig. 1, two methods are designed. To start with the multiple cell-based progressive energy efficient routing is constructed with the objective of reducing the energy consumption on broadcasting the message and reduces the time for identifying the shortest route path. Next, the trust-based route discovery is constructed using the trust value to provide trust level on broadcasting the message and therefore improve the packet delivery ratio. The elaborate description of the framework is discussed below.

Design of multiple cell-based progressive energy efficient routing: The first step in the design of multiple cell and trust-based progressive energy efficient routing framework is constructing multiple cells based on two-dimensional grid view. Initially, for minimizing the energy rate on multiple cell based broadcasting, MPEER follows the shortest path routing scheme. Multiple cell-based progressive energy efficient routing model on movable node starts by searching of the entire shortest route path in mobile ad-hoc network and picks up the minimal energy conservation path.

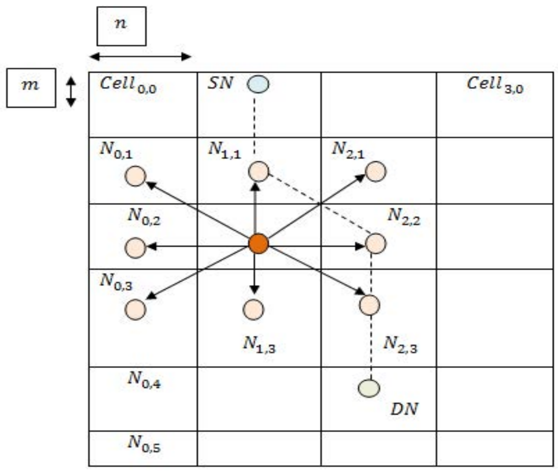

Fig. 2: Structure of multiple cell routing

Let us consider a Mobile Ad hoc Network consisting of mobile nodes '$Mn_i = MN_1, MN_2, ..., MN_n$' distributed in a given geographical area of M×N' with a communication range 'R'. The objective of multiple cell-based progressive energy efficient routing model is to search for the shortest route path that allows any source mobile node 'SN' to send to any destination node 'DN' through intermediate nodes '$N_i = N_1, N_2, ..., N_n$' a set of data packets '$DP_i = DP_1, DP_2, ..., DP_n$'.

The proposed Multiple Cell-based Progressive Energy Efficient Routing (MCPEER) model views the geographical region where the MANET nodes are located as 'm×n' two-dimensional multiple cell as shown in Fig. 2. Fig. 2 shows the structure of multiple cell routing.

As shown in Fig. 2, multiple cell based broadcasting is performed using MCPEER model where the width of a side of a cell is denoted by 'd'. The arrows in the figure represents the neighboring nodes whereas the dotted line represents the minimal energy conserved path arrived by applying MCPEER model. The source node 'SN' has to sent the data packet 'DN' to the destination node:

$$SN \rightarrow N_i[DN\ (DP_i)] \quad (1)$$

From Eq. 1, the source node 'SN' initially identifies the possible neighboring intermediate nodes 'N_i' possessing minimal energy conserving path. Two cells are called as neighbor cells if they have possesses common corner. So each cell possesses eight neighbor cells. Two mobile nodes in MCPEER model are called as neighbor nodes if they are located in neighbor cells in a multiple cell organization model. The value of 'd' is selected based on the transmission range 'R' such that each mobile node communicate directly with all other mobile nodes located in neighboring cells.

The shortest path in the '2D-cell' represents the sequence of neighboring cells and therefore constituting multiple cells. Therefore the shortest path 'SP' for the source node 'SN' is mathematically formulated as given in Eq. 2:

$$SP(SN) = \sum_{i=1}^{n} MIN(Energy(N_i)) \quad (2)$$

From Eq. 2 with the objective of minimizing the energy rate on multiple cells based broadcasting, MCPEER model follows the shortest path and picks up the minimal energy conservation path. The algorithmic description of multiple cell energy efficient routing algorithm.

Multiple cell energy efficient routing algorithm:

Input: source mobile node 'SN' Destination Node 'DN', Intermedaste nodes' $N_1 = N_2, ..., N_n$, Data packets '$Dp_i = Dp_1, Dp_2, ..., Dp_n$'
Output Energy efficiency routing
Begin
For each source mobile node 'SN'
Evaluate neighbour node using (1)
Evaluate shortest path with minimum enegy using (2)
End for
end

As shown in Algorithm 1, the multiple cell energy efficient routing algorithm performs two steps. In the first step, for each source mobile 'SN' to send the 'DP_i' to the destination node 'N_i' through the intermediate nodes 'N_i', neighbour nodes are identified. Followed by the neighbour nodes identification, minimal energy conservation path is identified aiming at minimizing the energy consumption on broadcasting the message.

Design of trust-based route discovery: Second, a trust based route discovery is carried out in MANET for packet transmission (i.e., message broadcasting) to the destination node. RREQ messages are forwarded to other neighbouring nodes and identify whether the route is a trusted route or not using the threshold value of the source mobile node. The threshold value is the energy consumption value attained on choosing the shortest route path. When the path is established, Route Reply (RREP) messages are forwarded though the same reverse route and the path is established for transmission. Figure 3 shows the Structure of Trust-based Route Discovery.

As shown in Fig. 4, whenever, a source mobile node has to transmit data packets to the destination node, route request messages 'RPEQ' are forwarded to the other neighboring nodes. As shown in the figure, the neighboring nodes are '$N_{0,1}, N_{1,1}, N_{2,1}, N_{0,2}, N_{1,2}, N_{2,2}, N_{0,3}, N_{1,3}, N_{2,3}$:

$$SN \rightarrow \sum_{i,j=1}^{n} RREQ(Energy(N_{i,j}) \quad (3)$$

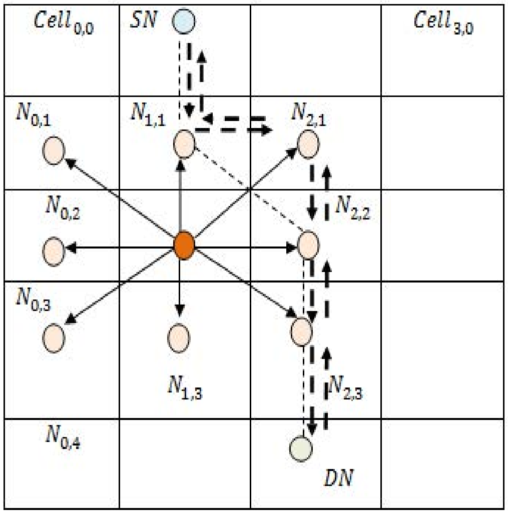

Fig. 3: Structure of trust-based route discovery

Where 'i,j' symbolizes the rows and columns in multiple cell organization. The trust-based route discovery uses the threshold value of the source mobile node. Therefore, trust-based route discovery identifies the path with the larger trust value of route andless delay of packet among multiple cells as two metrics unlike standard DSR protocol that only uses minimum hop count. The idea behind this is tomaximize the trust based route discovery by selecting the path that is expected to have higher threshold value. The threshold value is the energy consumption value attained on choosing the shortest route path and is formalized as given below:

$$\text{Trust}_{SN}(SP) = \text{Weight}_{SN}(N_i) \times \text{Trust}_{SN}(N_i)$$

Where 'Weight_{SN}' symbolizes the weight assigned to node 'N_i' by the source node 'SN' and 'Trust_{SN}' symbolizes the trust assigned to node 'N_i' by the source node 'SN'. Once the path is established, Route Reply 'RREP' messages are forwarded though the same reverse route in trust-based route discovery model and the path is established for transmission. Algorithm 2 describes trust-based route discovery algorithm.

Trust-based route discovery algorithm:

Input: Source mobile node 'SN' Destination Node 'DN', Intermedaste (neighbour) nodes' $N_i = N_1, N_2, ..., N_n$, Data Packets '$DP_i = DP_1, DP_2, ..., Dp_n$' 'α'
Output: Improved trust level on broadcasting the message
Step 1: Begin
Step 2: For each source mobile node 'SN'
Step 3: If threshold 'α'<SP (SN)
Step 4: Send route message 'RREQ' to neighbour nodes 'N_i' using (3)
Step 5: Measure shortest route path based on energy conserved route path using (4)
Step 6: Send reply message 'RREP' through the same reserve route
Step 7: Perform data packet transmission
Step 8: End if
Step 9: Threshold 'α'> SP (SN)
Step 10: Identyfy other route path
Step 11: End if
Step 12: End for
Step 13: End

Table 1: Simulation parameters

Parametrs	Values
Network area	1400×1400 m
No. of nodes	Oct-70
No. of data packet ie number of data block	9, 18, 27, 36, 45, 54, 63
Size of block data (ie packet)	100-512 kb
Range of communication	30 m
Speed of node	0-20 m sec
Simulation time	1500 sec
No. of runs	7

In Algorithm 2, the trust-based route discovery algorithm performs two steps for each source mobile nodes. To start with a route request message is sent to the neighboring nodes by the source mobile node.If the threshold value is less than the value of energy consumption attained on choosing the shortest path, then that path is selected and trustworthiness of that route path is measured. A route reply message is passed through the same reverse route and the path is established for transmission. Otherwise, another possible route path is identified and the iterations are repeated until, a trustworthy route is identified.

Experimental settings: In this study, the numerical data obtained as a result of applying MC-TPEER framework is presented. Table 1 lists the set of input parameter and evaluates performance of MC-TPEER framework via simulation. Our example MANET consists of 70 mobile nodes deployed in a square area of A^2 (1400×1400 m) placed in a random manner in the mobile ad hoc network that generates traffic for every 20 m sec^{-1}.

The mobile nodes are distributed in an area using Random Way point model for simulation, whereas the link layer provides the link between two mobile nodes and the design of link is multi direction. The base station collects the data packets of range 9-63 and forwards the data packets to the base station with each data packet size differing from 100-512 kb. The simulation time varies from 300 simulation seconds to 2100 simulation seconds.

RESULTS AND DISCUSSION

To validate the efficiency and theoretical advantages of the Multiple Cell and Trust-based Progressive Energy Efficient Routing (MC-TPEER) framework with Anonymous Location-Based Efficient

Table 2: Tabulation for energy consumption on broadcasting the message

	Energy consumption on broadcasting the message (J)		
Node density	MC-TPEER	ALERT	SP-MWN
10	56	68	75
20	64	76	83
30	75	87	94
40	82	94	101
50	72	84	91
60	88	100	107
70	90	103	110

Routing Protocol (ALERT) (Shen and Zhao, 2013) and Secure Payment Scheme for Multihop Wireless Networks (SPS-MWN) (Mahmoud and Shen, 2013), simulation results under NS2 are presented. The parameters of the MC-TPEERare chosen as provided in the experiment section.

Impact of energy consumption on broadcasting the message: Energy consumption on broadcasting the message at the sink node is measured using the energy consumed by a single mobile node with respect to the total mobile nodes in MANET. The energy consumption is mathematically formulated as given as:

$$EC = Energy_{MN} \times Total_{MN} \quad (4)$$

From Eq. 4, the energy consumption 'EC' on broadcasting the message is obtained by the product of the energy for single node '$Energy_{MN}$' and total mobile nodes '$Total_{MN}$' in the network. The consumption of energy is measured in terms of Joules.To better understand the effectiveness of the proposed MC-TPEER framework, extensive experimental results are reported in Table 2.

The NS2 simulator is used to experiment energy consumption on broadcasting the message by analyzing the result using table and graph values. Results are presented for different number of node density and the results reported here confirm that with the increase in the number of node density, the energy consumption also gets increased.

Figure 4 shows the energy consumption on broadcasting the message based on the node density in MANET considered for experimental purpose. Our proposed MC-TPEER framework performs relatively well when compared to two other methods ALERT (Shen and Zhao, 2013) and SPS-MWN (Mahmoud and Shen, 2013). The energy consumption on broadcasting the message is reduced in the MC-TPEER framework by applying multiple cell-based progressive energy efficient routing. By applying the multiple cell-based progressive energy efficient routing, efficient message broadcasting is performed using multiple cells routing model in mobile ad hoc network. Moreover, multiple cell-based progressive energy efficient routing identifies the neighboring nodes based on the minimal energy conserving path in a significant manner. This helps in reducing the energy consumption on broadcasting the message by 16.50% compared to ALERN (Shen and Zhao, 2013). With '2D-cell' using Multiple Cell-based routing, several data packets are broadcasted to the destination node in an efficient manner helps in reducing the energy consumption by 26.04% compared to SPS-MWN (Mahmoud and Shen, 2013).

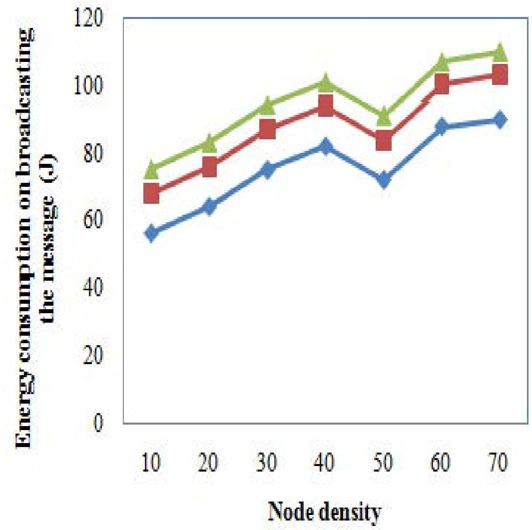

Fig. 4: Measure of energy consumption on broadcasting the message

Impact of shortest path identification time: The shortest path identification time is the time taken to identify the minimum energy conserved path through intermediate nodes with respect to node density. The shortest path identification time is formulated as given as:

$$SP_{time} = \text{Node density} \times \sum_{i=1}^{n} (\text{Time}(\text{Energy}(N_i))) \quad (5)$$

From Eq. 5, the shortest path identification time 'SP_{time}' is identified and is measured in terms of milliseconds (ms). Lower the shortest path identification time more efficient the method is said to be.

The targeting results of shortest path identification time using MC-TPEER framework with two state-of-the-art methods (Shen and Zhao, 2013) and (Mahmoud and Shen, 2013) in Table 3 is presented for comparison based on the node density in MANET.

Table 3: Tabulation for shortest path identification time

	Shortest path identification time ($m\ sec^{-1}$)		
Node density	MC-TPEER	ALERT	SP-MWN
10	10.5	13.6	18.5
20	163	19.4	34.2
30	241	27.2	32.1
40	20.4	23.5	28.3
50	28.6	31.7	36.5
60	25.3	28.4	33.2
70	32.9	35.4	38.1

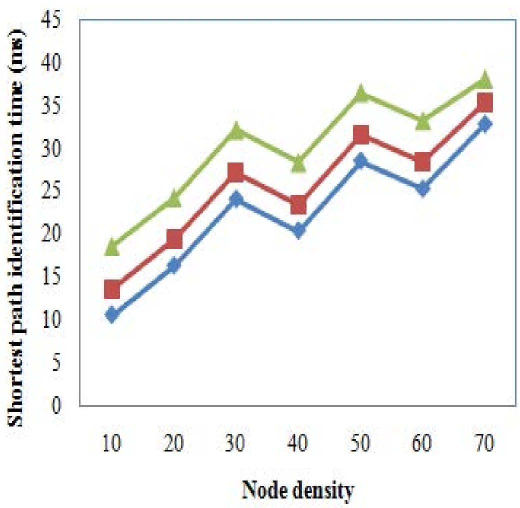

Fig. 5: Measure of shortest path identification time

From Fig. 5, it is evident that the shortest path identification time is reduced using the proposed MC-TPEER framework. Though the graph is not observed to be linear, but comparatively is lesser than the other two methods. The non linearity observed in the graph is due to the topology changes in MANET. The multiple cell energy efficient routing algorithm results in the improved shortest path identification time in MC-TPEER framework. With the application of Multiple Cell Energy Efficient Routing algorithm, sequence of neighboring cells constituting multiple cells with minimum energy conservation path is used at different time intervals resulting in the improvement of shortest path identification time. At the same time, in MC-TPEER framework, two neigbor cells possessing the common corner are used in multiple cells organization model to detect the route path in an efficient manner. This in turn minimizes the shortest path identification time sing MC-TPEER framework by 15.32% compared to ALERT (Shen and Zhao, 2013) and 38.74% compared to SPS-MWN (Mahmoud and Shen, 2013), respectively.

Impact of packet delivery ratio: Packet delivery ratio is the ratio of data packets sent to the data packets received through multiple cells in MANET. The packet delivery ratio is mathematically formulated as given as:

Table 4: Tabulation for packet delivery ratio

	Packet deleivery ratio (%)		
Node density	MC-TPEER	ALERT	SP-MWN
9	78.35	67.29	56.32
18	81.49	69.63	60.45
27	84.75	72.72	63.75
36	80.21	68.14	59.17
45	83.14	71.09	63.07
54	85.92	73.85	65.83
63	87.67	75.62	67.6

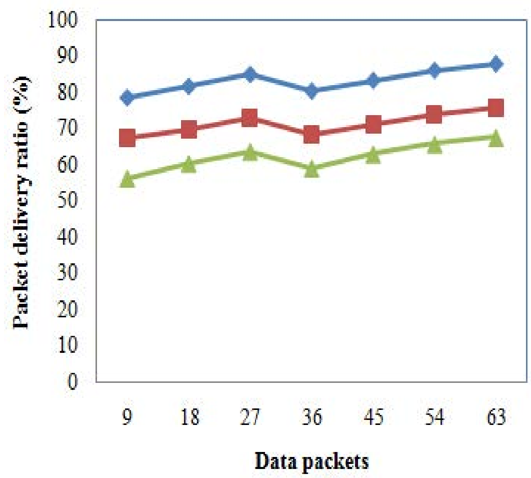

Fig. 6: Measure of packet delivery ratio

$$PDR = \frac{DP_r}{DP_s} \times 100 \quad (6)$$

From Eq. 6, the packet delivery ratio 'DPR' is measured using the data packets sent 'DP_s' and data packets received 'DP_r'. Higher the packet delivery ratio more efficient the method is said to be. It is measured in terms of percentage (%).

As listed in Table 4, MC-TPEER framework measures the packet delivery ratio in MANET with respect to data packets being sent. It is measured in terms of Milliseconds (ms). The packet delivery ratio using MC-TPEER framework offers comparable values than the state-of-the-art methods.

Figure 6 presents the variation of packet delivery ratio with respect to data packets in MANET. All the results provided in figure 8 confirm that the proposed MC-TPEER framework significantly outperforms the other two methods, ALERT (Shen and Zhao, 2013) and SPS-MWN (Mahmoud and Shen, 2013). The packet delivery ratio is improved in the MC-TPEER for data collection is reduced in the CS-FIS framework using the fuzzy-based inference model. Application of fuzzy-based Inference model, fuzzy membership function is applied to each sensor node. Followed by this, the sensed values are

Table 5: Tabulation for trust level on broadcasting the message

Methods	Trust on broadcasting the message (%)
MC-TPREE	78.32
ALERTS	64.16
SPS-MWN	58.32

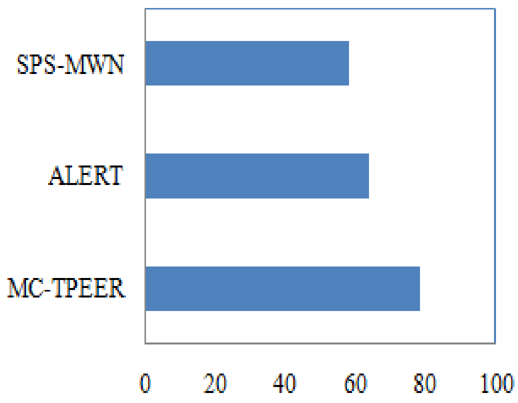

Fig. 7: Measure of trust level on broadcasting the message

mapped with the fuzzy values to perform fuzzy-based inference. This in turn reduces the energy consumption by 10.77% compared to ECD-WSN. As a result, energy consumption is reduced in the CS-FIS framework using the Fuzzy-based Inference model. Moreover, multiple event detection at different time intervals are also made in a significant manner by applying the fuzzy rule formation which in turn reduces the energy consumption during data collection by 17.65% compared to ESDA-WSN.

Impact of trust level on broadcasting the message: Table 5 and Fig. 7 shows the impact of trust level on broadcasting the message using three methods MC-TPEER, ALERT (Shen and Zhao, 2013) and SPS-MWN (Mahmoud and Shen, 2013). From the figure, it is evident that the trust level on broadcasting the message is improved using MC-TPEER framework. This improvement is because of the application of Trust-based Route Discovery algorithm that uses a threshold value as a base to choose the shortest path. The threshold value is derived from energy consumption value attained on choosing the shortest route path through which the trustworthiness of the route is measured. This in turn improves the trust level on broadcasting the message using MC-TPEER by 18.07% compared to ALERT and 9.10% compared to SPS-MWN.

CONCLUSION

In this study, Multiple Cell and Trust-based Progressive Energy Efficient Routing (MC-TPEER) framework is provided for mobile ad hoc network. This framework minimizes the energy consumption on broadcasting the message and therefore improves the trust level on broadcasting the message in mobile ad hoc network. As the framework multiple cell energy efficient Routing algorithm in a dynamic manner, it reduces the energy consumption on broadcasting the message in MANET through efficient selection of minimum energy conservant route path. As a result, the proposed multiple cell energy efficient Routing algorithm reduces the time for identifying the route path in an efficient manner and therefore improving the efficiency of the system and the overall network. Finally with the application of trust-based route discovery, efficient route discovery is obtained through the route discovery using a threshold as the basis for identifying the trustworthiness is performed in a significant manner and therefore improving the packet delivery ratio. Different mobile nodes with varied data packet sizes on MANET using MC-TPEER framework analyze the shortest route path to significantly improve the energy consumption on broadcasting the message and therefore the trust level in MANET. A series of simulation results are performed to test the energy consumption, shortest path identification time, packet delivery ratio and trust level on broadcasting the message and therefore to measure the effectiveness of MC-TPEER framework. Experiments conducted on varied simulation runs shows improvement over the state-of-the-art methods. The results show that MC-TPEER framework offers better performance with an improvement of energy consumption on broadcasting the message by 21.27% and improves the trust level by 13.50% compared to ALERT and SPS-MWN, respectively.

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