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Minimum energy consumption selection decode and forward routing protocol

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Mobile Ad hoc Network (MANET) is one of the complex tasks as topology changes frequently. Due to node mobility and node energy, rapid overtiredness due to limited battery power results in link breakages. Therefore topology, node mobility, and energy are the vital factor that has been affecting the performance of a routing protocol and reduce the overall network lifetime. A cooperative communication scheme called Minimum Energy consumption Selection Decode and Forward (MESDF) routing protocol, has been proposed in this paper to increase the network lifetime. Proposed routing protocol has included a cooperative table, a relay table, and a cooperative neighbor table to store the topological information. And that enforces cooperative transmission between the nodes, thereby enhancing robustness against the node mobility. Cooperative communication used multi-hop transmission between the source and destination nodes. That has determined the optimal route using the best possible relays with minimal energy consumption and considered link break probability and energy harvesting techniques to choose the optimal path. The simulation results clearly show that the robustness of the proposed method has increased against the node mobility and saved 21% of node energy in a selected approach which increased to 14% of the network lifetime compared to existing. cooperative and non-cooperative routing methods.

Keywords: Cooperative communication, MANET, MESDF, Routing protocol

1 Introduction

Mobile ad hoc networks have been the most widely used infrastructure-less network and play an important role in applications like military communications, emergency systems, conferences, and hotels. The deployment of ad hoc wireless network[1] is very easy because no-cables, no-configuration, and no-maintenance are required**,** and hence it has several benefits such as low cost, short time, re-configurability, and operates immediately. Moreover, MANET has several disadvantages like limited transmission range and regular link breaks due to mobility of nodes and fast overtiredness of energy. In order to address the above difficulties, a performance improvement frame structure was developed for MANET with cooperative communication is shown in below Fig. 1(a). The frame structure mainly concentrates on mobility models and protocol performance under different mobility rates. It has been observed that mobility rate increases due to node mobility and increases frequent link failures as well as transmission inefficiency, which in turn decrease the performance of routing protocol. In order to address the above difficulties, the MESDF routing protocol has been proposed in MANET, which improves the system capacity, network connectivity, reliability, and energy efficiency and decreases interference. Cooperative communication is one of the very important techniques for modern wireless communication systems and can improve energy efficiency and system capacity. A node in a cooperative network[2-4] can perform two roles during the transmission of data, such as a relay node and source node, which has to cooperate with the destination node and it tries to decode an entire input message and forward it to the next hop. The final route in the network has been selected based on the shortest energy distance.

The relay node has been significantly enhancing the reliability of communication among the nodes in a selected route. Cooperative communication allows multi hop transmission between the sending and receiving nodes in order to save energy and thus

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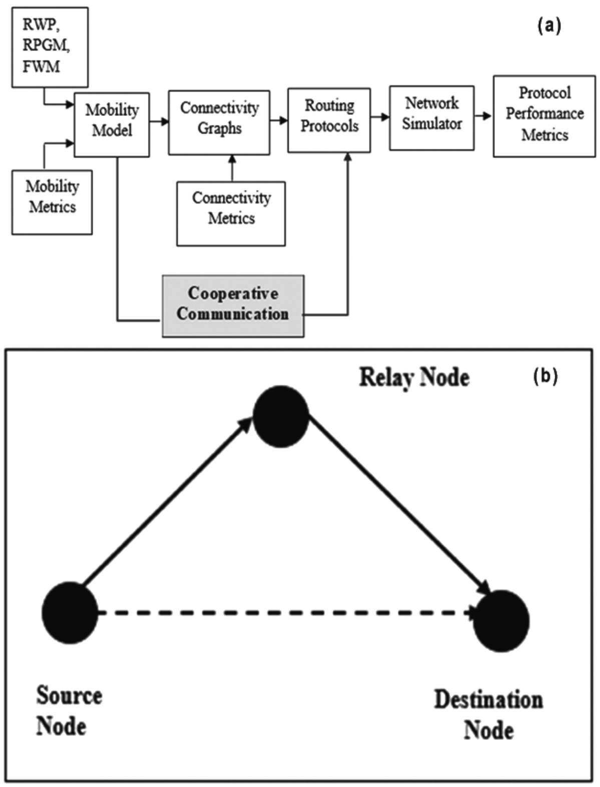

Fig. 1 — (a) Frame structure for improving robustness against node mobility[5], and (b) One hop cooperative wireless link between source and destination[2].

enhancing the lifetime of the network using MESDF routing protocol.

In this research paper, MESDF routing protocol selects the best relay with minimum energy consumption during transmission of data packets from source to destination. The best relays are identified based on number of neighboring nodes and remaining battery energy which minimize the energy consumption and improves transmitting data rate. Furthermore, the results of the proposed scheme are compared with the existing cooperative scheme called Constructive Relay-based Cooperative Routing (CRCPR)[5] and non-cooperative scheme called AODV protocol.

An example of one-hop cooperative wireless link is shown below Fig. 1(b). Each node in a cooperative network can perform two important roles during transmission of data called as source node and relay node. Here, the main attractive feature of cooperative communication has been a relay transmission. The nodes with EH ability in the network tried to find the route with minimum transmission cost with energy count and compared the results with Xinbing wang[2].

Therefore, fast exhaustion of node energy due to limited battery capacity which leads to limit the lifetime of MANETs. J. Bai[5] has proposed a constructive relay based cooperative routing (CRCPR) scheme to enhance the robustness of mobility issues and considers energy consumption method to improve the throughput and prolonged the network lifetime and tried to find the routes with minimum hops, less energy consumption and appropriate traffic load balancing in a combined way. A cooperative routing protocol called CRCPR protocol has the following drawbacks:

1 Link break frequency increases quickly when number of mobile nodes becomes higher.
2 Relay nodes that have been selected randomly hence increases the overall energy consumption.
3 It has been implemented based on shortest path and performance improvement of CRCPR could not be fully exploited.

As a contrary, MESDF routing protocol has been proposed in MANET.

2 Materials and Methods

It is a table-driven with on-demand cooperative routing protocol. Table-driven means cooperative topology is constructed in advance for all sources to destination pairs and on-demand means route is constructed only when required to forward the data to the intended destination nodes in the network. MESDF routing protocol uses two types of tables that is cooperative table and relay table for maintaining and storing the topological data. The main use of relays in the network is to transmit information between source and destination node and is a very effective technique to increase energy efficiency. Because, the distance between source and relay node is shorter related to distance between source and destination nodes, that means its possible to decrease the transmission energy on both sides of the relay nodes.

2.1 COP Table

It was created to use COP (cooperative) topology with four nodes. The first node (IN1) was assumed as COP source node and second node (IN2) as COP destination node in the COP topology. The remaining nodes are called the intermediate nodes (IN3 and IN4). Before forwarding the data by the COP source node, it selected an appropriate entry from its COP table list and placed this entry in COP conformation packet. Then COP information was forwarded to both the intermediate nodes to be ready for transmission of data. After conforming the COP table in the COP topology, starts forwarding the data. The COP technique is shown in above Fig. 2(a).

The main application of relay node between sender and receiver nodes permits to improve the performance and energy savings. Relaying generally splits longer routes into shorter route segments thereby decreasing total route damage due to non-linear relationship of path loss and path distance. Replacing longer paths and associated losses became an advantage of cooperative communication with shorter and robust radio links.

2.2 Relay Table

After updating the COP neighboring table using hello packet, all the intermediate nodes deleted the invalid entries when COP topology did not exist. When entry was deleted from COP table, the COP nodes in this entry acted as neighboring node and created a relay table. The relay table generally consisted of two relay neighbors and corresponding IP addresses respectively. An example for creation of relay configuration for IN2 and IN4 is shown in above Fig. 2(b).

In this research, three simple steps were adopted to implement the MESDF routing function

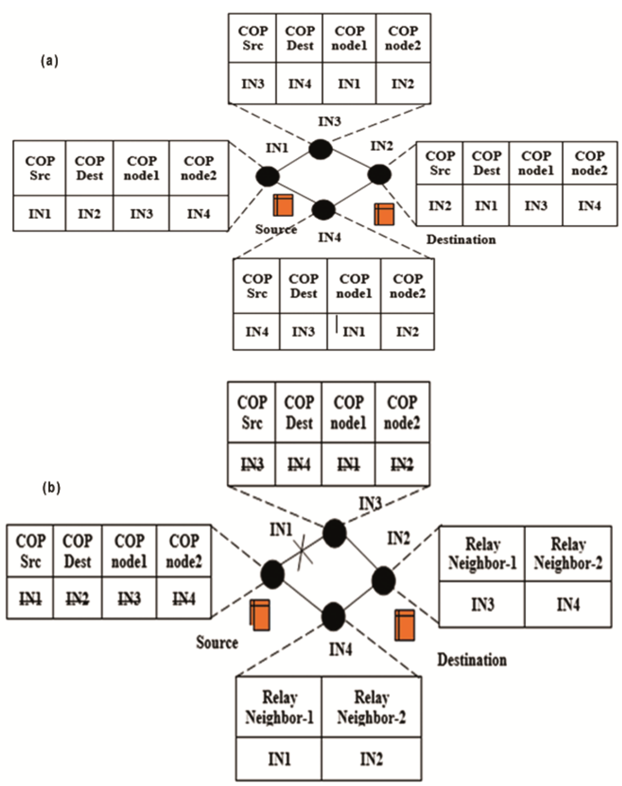

Fig. 2 — (a) Cooperative technique[5], and (b) Relay configuration[5].

1 To establish cooperative link between source and destination nodes using the best possible relay nodes.

2 If any link failures in the route, select new relay nodes to improve the connectivity and reliability thereby enhancing the performance.

3 Final route was selected based on the minimum number of link failures.

The MESDF routing identified the best relays based on the number of neighboring nodes and remaining battery energy which realized the minimum energy consumption in a selected route. The proposed routing protocol compared its performance in terms of outage probabilities for direct transmission and cooperative transmission between the source and destination nodes and corresponding mutual information was compared with the existing CRCPR scheme and is given by

$$I_D = \log(1 + \rho \, |a_{s,d}|^2) \quad \ldots(1)$$

where, $\rho = E_b/N_o$ is the transmission power to noise power ratio, E_b represents the transmission energy per bit and N_o is the white noise, $a_{s,d}$ represents the wireless link between source and destination.

The outage probability for direct transmission between the nodes is given by

$$P_D^{out} = d_{s,d}^{k} \left(\frac{2^R - 1}{\rho}\right) \quad \ldots(2)$$

where, R represents the desired data rate in bit/s/Hz and d is the distance between source and destination nodes. For cooperative transmission, the distance among the source, relay and destination nodes are given by the following equations.

During first time slot, source node in the network broadcast the CREQ (cooperative route request) packet to rest of the nodes in the network and estimate the distance between source and relay through the received signal strength. Similarly, during second time slot destination node broadcasts another CREQ packet with information and estimated the distance between relay and destination node and received the information via relay node is

$$y_d = \begin{cases} \dfrac{h_{s,d}}{d_{s,d}^{k/2}} x_s + n_d \text{ , if } |\dfrac{h_{s,d}}{d_{s,d}^{k/2}}|^2 < q(\rho_s) \\ \dfrac{h_{r,d}}{d_{r,d}^{k/2}} x_r + n_d \text{ , if } |\dfrac{h_{s,r}}{d_{s,r}^{k/2}}|^2 \geq q(\rho_s) \end{cases} \quad \ldots(3)$$

where, $q(\rho_s) = (2^{2R} - 1)/\rho_s$ was derived from direct transmission, destination node received the information $y_d = \frac{h_{s,d}}{d_{s,d}^{k/2}} x_s + n_d$ from source node, where, x_s denoted information transmitted by source node, $h_{s,d}$ is the channel, $d_{s,d}^{k/2}$ represented the distance between source and destination nodes, k is the path loss exponent and n_d represented the white noise.

In the proposed scheme mutual information could be written as

$$I_C = \begin{cases} \frac{1}{2}\log(1 + 2\rho_s\ |a_{s,d}|^2), |a_{s,r}|^2 < q(\rho_s) \\ \frac{1}{2}\log(1 + \rho_s\ |a_{s,d}|^2 + \rho_r |a_{r,d}|^2), |a_{s,r}|^2 > q(\rho_s) \end{cases} \quad \ldots(4)$$

Therefore, the outage probability for MESDF routing is given by

$P_C^{out} = Pr\,[I_C < R]$ and

$$P_C^{out} = \frac{1}{2} d_{s,d}^k \left(d_{s,r}^k + \frac{\rho_s}{\rho_r} d_{r,d}^k \right) \frac{(2^{2R}-1)^2}{\rho_s^2} \quad \ldots(5)$$

where, ρ_s and ρ_r indicates the ratio of transmission power to noise power for source and relay nodes, and therefore, $I_C < R$ means increasing the performance of cooperative network. The proposed scheme always attains greater energy performance when compared to CRCPR protocol.

3 Results and Discussion

In order to investigate the performance of MESDF, routing protocol was required to use the network simulator. In general, AODV is most widely adopted because it has no exact structure to avoid link breakages. So, frequent link break would rise quickly when the number of mobile nodes in the network increases. Furthermore, CRCPR was selected as other baseline and used cooperative table, cooperative neighbor table and relay table to store the topological information and implement cooperative transmission among nodes thereby improving the robustness against the node mobility. The performance metrics were examined by varying the number of mobile nodes and energy restricted nodes[6,7]. The following are the important parameters required to simulate the cooperative network and are given in below Table 1.

3.1 Number of link failures

The simulation results shown in below Fig. 3(a), which showed the frequent link breaks of the three protocols used in a scenario with 50 nodes. For AODV, it has no specific scheme to avoid link breaks. So, the link break frequency would automatically increase when number of mobile nodes increases. In CRCPR protocol, the link break frequency would decrease via the cooperative and relay table up to certain limited number of nodes. If the number of mobile nodes increased then the link break frequency would also increase quickly. But in proposed method that is in MESDF routing protocol, number of mobile nodes increased with higher value, the frequency of link breaks was much lower than CRCPR protocol.

3.2 End-to-end delay

In Fig. 3(b), it was observed that when number of mobile nodes involved in a scenario with 50 nodes, the end-to-end delay of all the three protocols would vary significantly. The end-to-end delay of AODV was higher because there is no specific scheme for avoiding link breaks. More specifically, due to link break reduction the end-to-end delay of CRCPR and MESDF were more stable when compared with AODV if increasing the mobile nodes and provided better performance. The mathematical expression for end-to-end delay is given by

$$End\ to\ End\ delay = \frac{\sum_{i=0}^{n}(time\ of\ packet\ received - time\ of\ packet\ sent)}{Total\ number\ of\ data\ packets\ received} \quad \ldots(6)$$

3.3 Throughput

From Fig. 4(a), it was observed that throughput of AODV decreased with increasing the mobile nodes in a network. But, the performance of CRCPR and MESDF was more stable and better than AODV because it could utilize the cooperative topology to improve the robustness against the node mobility. Furthermore, the final route selection criteria of CRCPR and MESDF would avoid a node with high link break probability. So, a more stable route would

Table 1 — Parameters used for the simulation

Parameter	Assigned value
Initial energy	0.1 J
Data rate	2 Mb/s
Speed	10 m/s
Number of nodes	50
Packet size	64 Kbps
Simulation time	250 Sec.
Network area	1000 m^2
Routing protocol	AODV, CRCPR and MESDF
Mobility model	Random walk
Energy model	Wi-Fi radio energy model
Wi-Fi channel	Yans Wi-Fi

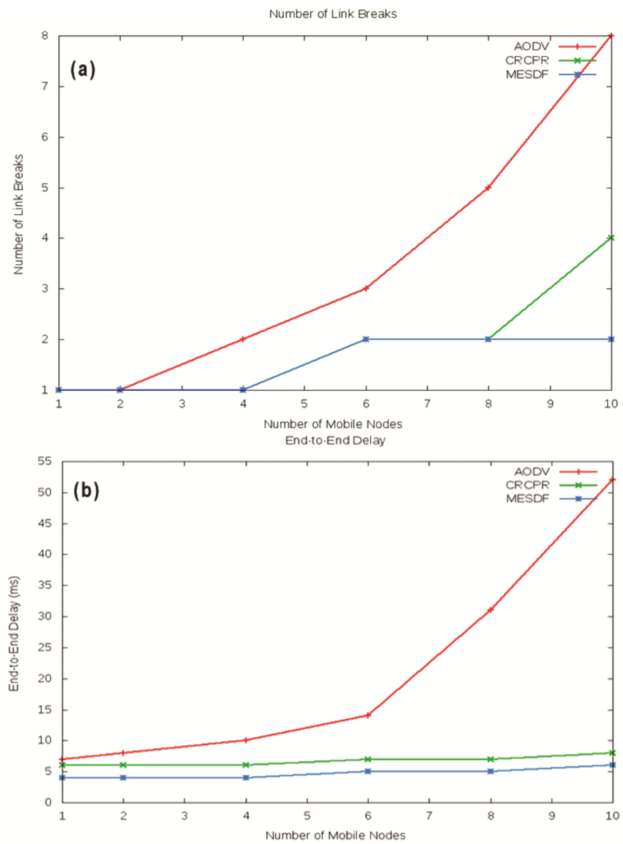

Fig. 3 — (a) Number of link breaks Vs Number of MN in a network[5], and (b) End-to-end delay vs Number of MNs in a network[5].

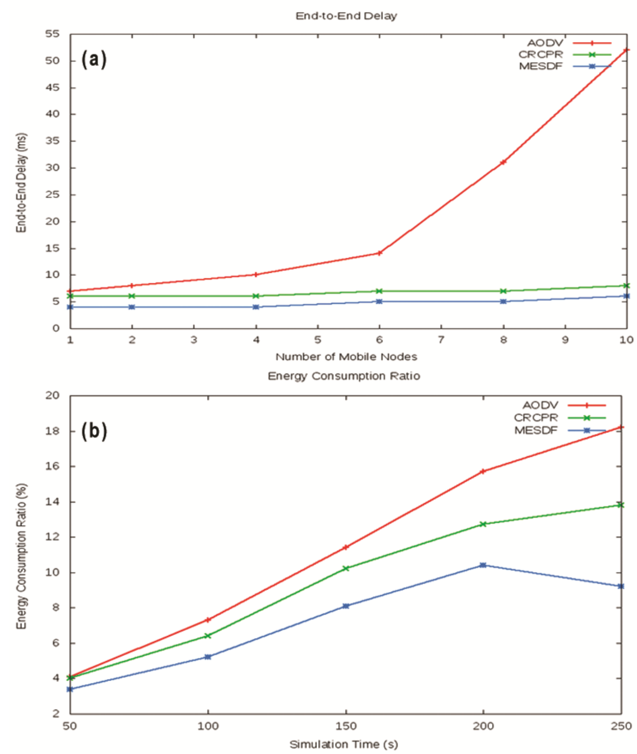

Fig. 4 — (a) Number of link breaks Vs Number of MN in a network[5], and (b) Energy consumption ratio vs Simulation time[5].

be selected than the shortest path and improved the network throughput. Therefore, throughput is expressed and is given by

$$Throughput = \frac{File\ size}{Transmission\ \ time\ \ (bps)} \quad \ldots(7)$$

where, $Transmission\ time\ in\ bps = \frac{File\ size}{Bandwidt\ h}$

3.4 Energy consumption

The simulation result in Fig. 4(b), which shows that the energy consumption rate of the three protocols used in a scenario with 50 nodes. For AODV, there was no specific scheme to avoid link breaks. So, the link break frequency would automatically increase when number of mobile nodes increased thereby consuming more energy when compared to other protocols. In CRCPR, the link break frequency would also decrease due to cooperative communication via the cooperative and relay table and consumption of energy was somewhat less than AODV protocol. But in the proposed method that is in MESDF protocol, it consumed less energy for a selected route when compared to existing protocols. The mathematical expression for energy consumption[8-10] (EC) is given by

$$EC = \frac{Total\ energy\ consumption}{Total\ number\ of\ data\ packets\ delivered\ to\ destination\ node} \quad \ldots(8)$$

3.5 Network lifetime

It was nothing but the duration of the network until the first or last or any node along the route knowledge energy was drained out. The overall network lifetime of three protocols is shown in below Fig. 5. In order to compare the lifetime of the three protocols it needed to deactivate the energy harvesting (EH) ability and change the role of mobile nodes to energy restricted (ER) node, which assigned lower energy than the normal nodes[11-14]. With increasing the ER nodes, the overall network lifetime of both AODV and CRCPR reduced. When the number of ER nodes was lower, the performance of MESDF was better and remained stable due to its route selection criteria and energy harvesting which in turn increased the lifetime of the network.

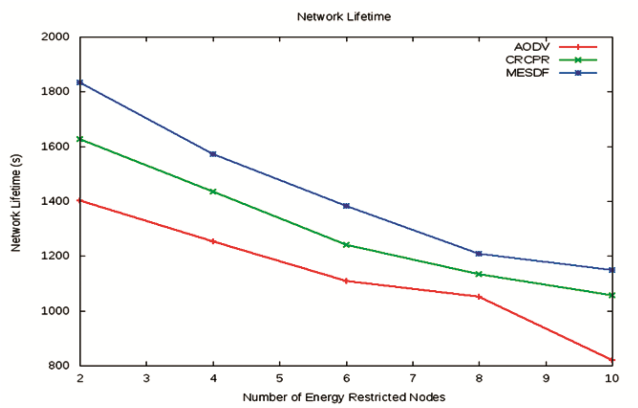

Fig. 5 — Network lifetime Vs Number of energy restricted nodes in a network[5].

4 Conclusion

Major problem with MANET has been frequent link breakages due to node mobility and fast energy exhaustion due to limited battery power which in turn decreases the network lifetime. In order to address the above issues cooperative communication technique has been used here that played an important role for improving system capacity and energy efficiency of a MANET using best relay nodes. The use of relay node is to transmit the information between sender and receiver in an effective manner and increase energy efficiency because the distance between sender and relay is very shorter compared to distance between sender and receiver, which means reduction in transmission energy on both sides have been possible. Proposed routing protocol selects the optimum route based on minimum energy consumption during transmission of data through the best relay nodes and increases the energy efficiency thereby enhancing the lifetime of the network when compared to existing schemes. The simulation result shows that proposed routing attains 21% of energy saving in a selected route when compared to existing cooperative and non-cooperative routing methods. Therefore, the proposed scheme has given better performance and prolonged 14% of network lifetime over the existing methods.

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