# Message Ferry Route Calculation through K-means Clustering Algorithm for Partially-Connected MANET

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## Abstract

Partially-connected MANETs are the Wi-Fi networks where most of the time a comprehensive path between source and destination does not exist due to narrow radio transmission range of the nodes, low density of nodes, wide deployment area, physical obstacles like high rise buildings, severe weather conditions, or other physical factors. The traditional routing protocols of the Mobile Ad-hoc Network presume that the network is connected. There are two possible solutions to solve the connectivity problem in sparse MANET. The first solution makes use of random movement of nodes to transfer messages whereas in the second, one node is given special privileges to roam in the deployment area to distribute messages in segmented areas, which is also called the Message Ferry (MF) approach for transmitting data. Message ferries keep moving in the deployment area and take the charge of storing, carrying and forwarding data of the regular nodes. In the present paper, the ferry-initiated approach has been adopted with 2 ferry nodes, which are allowed to move in such a way that they cover the maximum area of the grid. It is proposed that the ferry nodes will design their routes dynamically on the basis of current topology of MANET and in one round trip it will pass through the centers of the partitioned clusters formed by the regular nodes. The process of calculating cluster center is repeated in further trips. K-means clustering algorithm is applied to calculate the cluster centers of the partitioned clusters. The results indicate positive performances of the proposed model in various simulation experiments conducted.

## Keywords

K-means Clustering Algorithm, Partially Connected MANET, Sparse MANET, DSR, Message Ferry, ns2.

## Introduction

With the advancements in computer and wireless technologies, mobile computing is expected to see enormous use and application. Mobile devices, such as cellular phones, e-readers, PDAs, laptop computers, Tablets, UMPCs, smart watches (Mani, Singh, Pandey, Srivastav, & Yadav, 2019)and smart phones can be found on everyone from youngsters to senior citizens. Wireless networks are now part of almost every aspect of our lives. As the wireless devices are getting smaller, cheaper, and more refined, they turn out to be more widespread and industry is looking for cheaper ways to connect them.

As the usage and the importance of mobile devices in our day-to-day life rises, it also puts new demands for sophisticated solutions for connectivity. Solutions for wired networks have been around for quite a long time, even then the demand for connectivity between various mobile devices in wireless environment is increasing day by day.

Few solutions to such requirements such as wireless LAN that is built on IEEE 802.11 standard are there. However, there is an increasing demand in industry for connectivity between mobile devices in situations where there is no base station available. MANET (Miao, Sun, Wang, & Cruickshank, 2015) has a self-configuring setup where every node serves as a potential router irrespective of any centralized authority(Corson & Macker, 1999; Haas, Deng, Liang, Papadimitratos, & Sajama, 2002).

All the routing algorithms (Sarkohaki et al., 2014) written for MANETs assume that the network is connected. This supposition limits these routing protocols to the networks where there are sufficient nodes to create a completely connected topology. Unfortunately, the intermittent connectivity in MANET(Aram et al., n.d.)(Jiang, Xu, Yao, Bui, & Chen, 2018)might arise from the mobility of nodes, power limitations, wide deployment space, short communication range, intermittent node density, severe weather, or different physical factors and so on, and thereby most often a complete end-to-end path between communicating nodes either does not exist or such a path is very unsteady and break soon once it has been discovered.

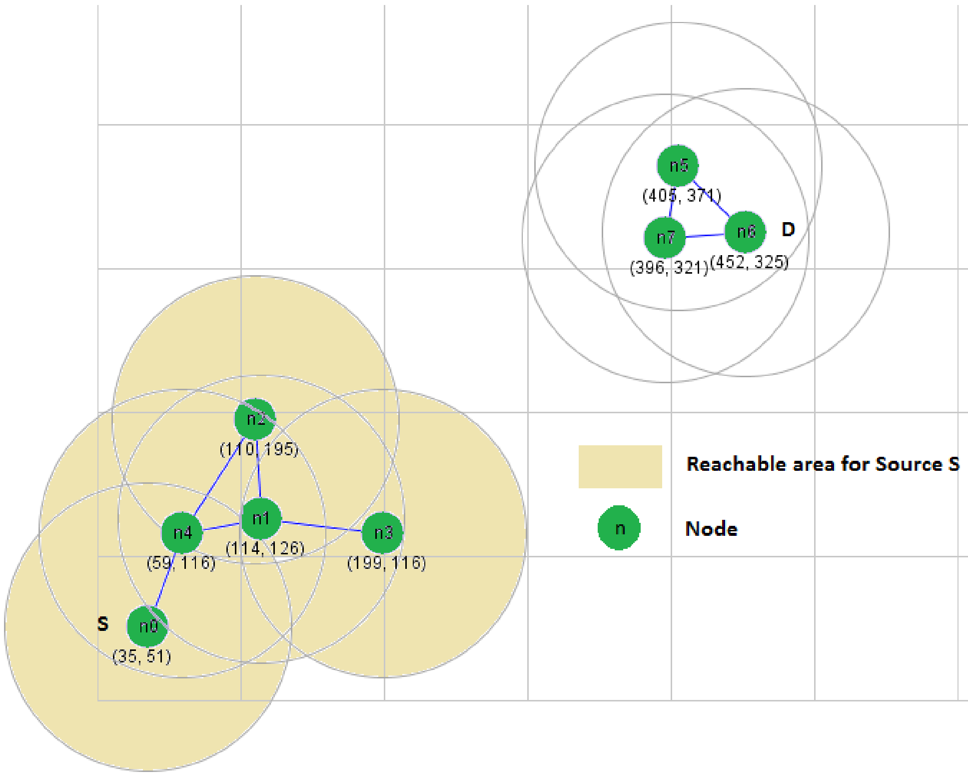


**Figure 1 Partitioned Network Scenario**

Partially-connected MANETs with a long disconnection period creates segmentation in network. Figure 1 displays an example of a sparse network where the coverage area of source node S is presented by peach colour. It is clear from the figure that the source node S is not able to exchange information with the destination node D resulting in network segmentation.

Existing routing algorithms (Perkins & Royer, 1997), (Johnson, Maltz, & Broch, 2001), (Perkins & Bhagwat, 1994), (Clausen, Jacquet, & Viennot, 2002; Ubnare, Manghi, & Shukla, n.d.) merely discard the packets if it does not reach destination within a specified span of time. Failure of these algorithms in Partially-connected scenario is mainly due to:

- Frequent disconnections.
- Highly variable link performance
- Intermittent network contacts

- Lack of end-to-end pathway between communicating node.

## Related Work

Epidemic Routing Scheme (Vahdat & Becker, 2000), applies brute force methodology to distribute messages in a partitioned network. This scheme makes use of mobile nature of the hosts and follows "store-carry-forward" model where each node acts as a relay node to other nodes. The algorithm basically follows flooding algorithm with small variations to scale back overhead.

With this transitive way of distributing messages, the message can hope to reach the destination node present in the segmented cluster. In the Modified Epidemic Routing Scheme (Davis, Fagg, & Levine, 2002) it is proposed to exploit the node mobility statistics in order to overcome the drawbacks of epidemic routing. In this routing scheme the nodes guess the possibility of interacting with other nodes from this time forth and advance their messages based on these guesses. In this way this scheme gives better result as compared to normal epidemic routing.

In a Message Ferry (MF) (Ad, Zhao, Ammar, & Zegura, n.d.) scheme, few nodes in the network take up the role of message ferries (or ferries for short) which are devices that are given the duty of transporting messages between different nodes. This scheme can be applied in various scenarios like disaster relief, battlefields, non-interactive internet access, wide area sensing and secret communication.

In Message Ferry Routing Approach (Zhao, Ammar, & Zegura, 2004), the authors proposed a special delivery node referred to as a ferry node with greater transmission range and having a fixed path to move. The regular nodes can move randomly but remain immobile mostly. They also proposed two different approaches for communication namely, Node-Initiated Message ferrying (NIMF) and Ferry-Initiated Message ferrying (FIMF) approach.

In Clustering based approach (Bentaleb, Boubetra, & Harous, 2013; Lee, Yu, & Moh, 2004; Tao & Wang, 2012), the network is partitioned into small sets of nodes which are in geographical proximity with each other. Several algorithms have been proposed to solve the inter and intra cluster communication issues. Clustering helps in simplifying the data packet routing and reducing the control traffic.

Each cluster has a process to elect a Cluster Head (Dang & Wu, 2010)based on its mobility, weight, density, identity etc. Within a cluster the Cluster Head acts like a coordinator between regular node and Gateway node (a common node among neighboring clusters).Out of various schemes for clustering Weight based clustering scheme is most famous which uses weight metrics like battery, transmission power, mobility etc. to elect Cluster Head.

As discussed in (Chaintreau et al., 2006; Jindal & Psounis, n.d.; Kim & Kotz, 2006; Lee et al., 2004; Lindgren, Doria, & Schelen, 2004) the frequency of a node to visit a particular location may be high or low. (Dang & Wu, 2010) tries to learn the mobility pattern of nodes and group the nodes with same pattern into one cluster in Delay Tolerant Mobile Network by using Exponentially Weighted Moving Average.

For Pocket Switched Networks a forwarding algorithm is discussed as BUBBLE algorithm (Hui, Crowcroft, & Yoneki, 2008) based on social structure of human mobility patterns. The BUBBLE algorithm elects high-centrality nodes i.e. nodes which can interact with more nodes and gives good forwarding efficiency over PROPHET(Lindgren et al., 2004) algorithm.

The rest of the paper is organized as follows: In Sec. IIIa model of finding message ferry route is proposed through cluster centers. In Sec. IV simulation setup is given. Sec. V presents results and discussions. Finally, Sec. VI concludes the paper.

## Proposed Model: Message Ferry Route through Cluster Centers

Message Ferries are special transport units that exploit the non-randomness in the movement of the node to deliver data between disconnected nodes. The most important vital issue in this approach is to design the route of the ferry node (Miura, Nishi, Matsuda, & Taki, 2010; C. F. Wang, 2012; T. Wang & Low, 2011). Hence, in this paper a new model is proposed to solve the problem of connectivity in partially-connected MANETs. This model called “Message Ferry Route through the Cluster Centers” (MFR-CC) is implemented on Dynamic Source Routing Protocol (DSR) which is the example of On-demand Routing Protocols (Reactive). Some of the salient features of the proposed model are as follows.

### A. Use of Multiple Ferries

The use of a single ferry node is simple, but it cannot perform well for large network scenarios and high traffic load. In the modified Message Ferry Approach, it has been tried to reduce the chance of failure by introducing one more ferry node. Multiple ferries are required because of their high performance and robustness. On the flip side it brings little complexity to the ferry route design algorithm and can increase the system cost also.

### B. Dynamic Ferry Route

In this paper we propose that the ferry node will follow dynamic route in every run taking current topology into account. The ferry-initiated approach has been adopted here with 2 ferry nodes, which are allowed to move in such a way that they cover the maximum area of the grid. It is suggested that the ferry nodes will calculate their routes dynamically on the basis of the current topology of MANET.

### C. Cluster Centre Calculation Using K-Means Clustering Algorithm

K-means clustering (Kanungo et al., 2000) or popularly known as cluster analysis in data mining comes under unsupervised learning procedure used for data categorization which means that there is no label or tag to guide the learning process or no established measurements of the outcomes since we want to find them out. Unsupervised learning can be categorized into clustering and association. Clustering means grouping up of a set of objects or nodes in a fashion that objects in the same cluster or group have some sort ofas compared to those in other clusters.

K-means uses a repeated refinement procedure to produce its final clustering built on the number of clusters defined by the user (represented by the variable *K*) and the dataset. For example, if we set K equal to 4 then our dataset will be grouped in 4 clusters, if we set K equal to 5 we will group the data in 5 clusters, and so on.

### Algorithm

a) Group the regular nodes into k clusters where k is predefined.
b) Select k nodes at random as cluster centers in such a way that they are placed far away from each other.
c) Assign nodes to their nearby cluster according to the Euclidean distance or Manhattan distance function.
d) Calculate the cluster center or mean of coordinates of all nodes in each cluster.
e) Repeat steps b, c and d until the same nodes are assigned to each cluster.

### D. Waiting Time At Cluster-Centres

The ferry nodes follow the dynamic route discussed above and take some halt at the cluster-centres in order that the ferries can come across each other with a definite probability.

### E. Data Transfer

The ferry node continuously monitors its buffer for any data transportation request. If there is any such request, it starts searching for a route to the destination and forwards these packets to destination node's buffer.

### F. Greater Transmission Range for Ferries

In the proposed model the ferry node has a high-power antenna so that it can communicate with the regular nodes at ease.

## Simulation Experiments

In this paper, the simulation results of implementation of the MFR - CC Model on DSR protocol are discussed. In this study 14 regular nodes are taken as shown in Figure 4. As it is clear from the figure that the present structure of MANET is forming 4 clusters which are partitioned from one another.

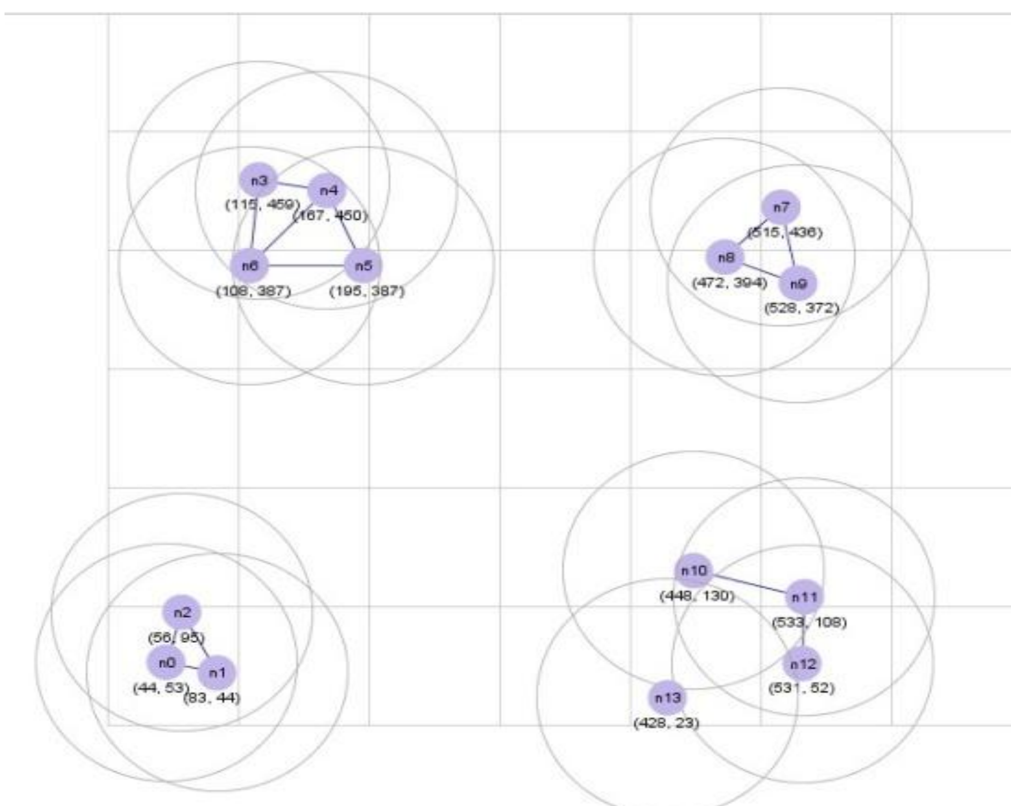


**Figure 2 Scenario of Partitioned MANET**

The coordinates of 14 regular nodes are shown in Table 1. Since these nodes form 4 clusters, Cluster Centers (CC) can be calculated using the K-means algorithm.

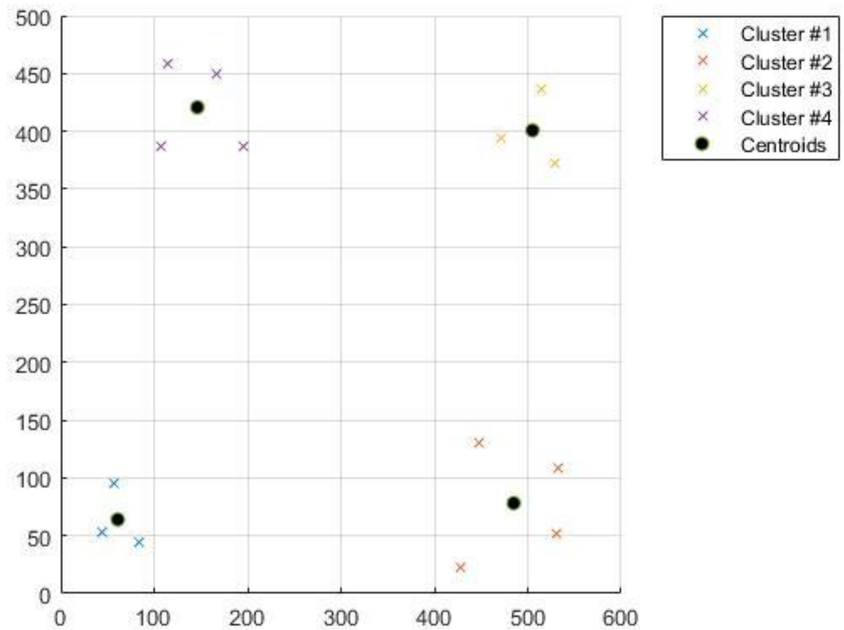


**Figure 3 Cluster Centres Calculation Using K-Means Clustering Algorithm**

After the calculation of centroids of the clusters, Cluster Center Coordinates are presented in Table 1.

**Table 1 Coordinates of the MANET Nodes**

| Node | X | Y | Cluster | CG Coordinates of Cluster |
|---|---|---|---|---|
| **Regular Nodes** | | | | |
| n0 | 44 | 53 | Cluster 1 | (61, 64) |
| n1 | 83 | 44 | | |
| n2 | 56 | 95 | | |
| n3 | 115 | 459 | Cluster 2 | (146, 418) |
| n4 | 167 | 450 | | |
| n5 | 195 | 387 | | |
| n6 | 108 | 387 | | |
| n7 | 515 | 436 | Cluster 3 | (505, 401) |
| n8 | 472 | 394 | | |
| n9 | 528 | 372 | | |
| n10 | 448 | 130 | Cluster 4 | (480, 77) |
| n11 | 533 | 108 | | |
| n12 | 531 | 52 | | |
| n13 | 428 | 23 | | |
| **Ferry Nodes** | | | | |
| n14 | 61 | 64 | | |
| n15 | 505 | 401 | | |

Cluster Centers (CCs) can now be taken as Optimized Way Points (OPWP) through which the ferry will move. Now the 4 OPWPs are connected to form Ferry Route for the first dynamic run. For the successive runs the ferry route will be calculated on the basis of the changed locations of the regular mobile nodes.

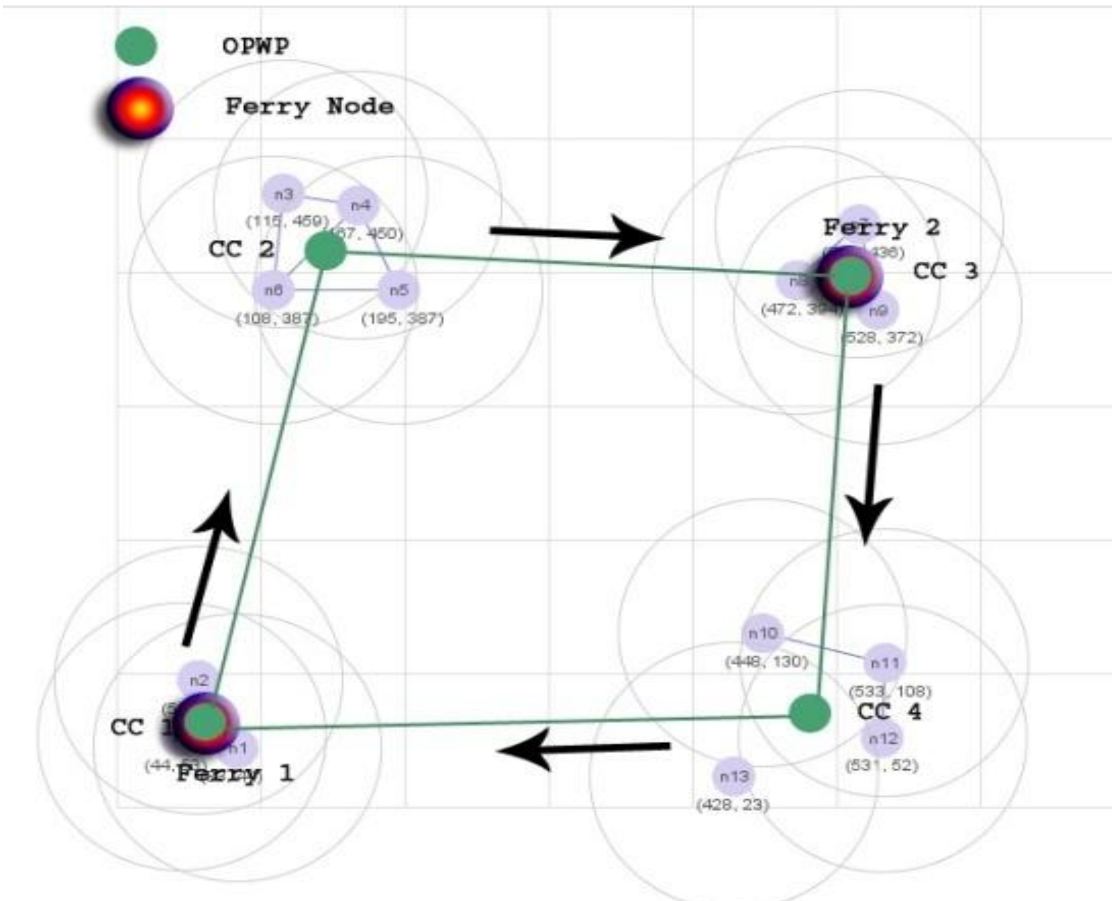


**Figure 4 Opwps And Ferry Route Design**

Ferry nodes will start their journey from any 2 of the CCs. In the present scenario, the CCs of Clusters 1 and 3 are taken as starting points of their journey for the first dynamic run. Both ferries will move with a speed of 9 m/s and take a halt of approximately 10 seconds at the CCs. The departure and halt timings of ferry nodes from the various Cluster Centers (CCs) as taken in the simulation carried out in ns2 have been presented in Table 2 & 3.

**Table 2 Passage of Ferry Node 1 (N14) through Various CCS**

| **Clusters** | **CC (C1)** | **CC (C2)** | **CC (C3)** | **CC (C4)** | **CC (C1)** |
|---|---|---|---|---|---|
| Ferry 1 starts at t= | 10 sec. | 60 sec. | 110 sec. | 156 sec. | 212 sec. |
| Halt (Approx.) | 10 sec. | 10 sec. | 10 sec. | 10 sec. | 10 sec. |

**Table 3 Passage of Ferry Node 2 (N15) through Various CCS**

| **Clusters** | **CC (C3)** | **CC (C4)** | **CC (C1)** | **CC (C2)** | **CC (C3)** |
|---|---|---|---|---|---|
| Ferry 1 starts at t= | 10 sec. | 56 sec. | 113 sec. | 164 sec. | 213 sec. |
| Halt (Approx.) | 10 sec. | 10 sec. | 10 sec. | 10 sec. | 10 sec. |

The analysis of the simulation results of the proposed model brought forth by the Network Simulator (ns2). In the simulation of the proposed model the various parameters that are considered for the simulation are listed in Table 4.

**Table 4 Simulation Parameters**

| **Parameter Name** | **Value** |
|---|---|
| Channel Type | Channel/Wireless Channel |
| Propagation Model | Propagation/Two Ray Ground |
| Netif | Phy/Wireless Phy |
| Mac Protocol | Mac/802_11 |
| Queue Type | Queue/Drop Tail/Pri Queue |
| Queue Length | 50 |
| Link Layer Type | LL |
| Antenna Type | Antenna/Omni Antenna |
| Number of Nodes | 16 (14+2) |
| Regular Nodes | n0-n13 |
| Ferry Nodes | n14, n15 |
| Regular Node Speed | 1 m/s |
| Ferry Node Speed | 9 m/s |
| Halt Time at CCs | 10 sec. (approx.) |
| Routing Protocol | DSR |
| Grid Size | 600 x 500 |
| Packet Size | 512 |
| Simulation Time | 225 |
| Node Range | 250 Meters |
| Topology | Random |
| Agent Trace | ON |
| Router Trace | ON |
| MAC Trace | ON |
| Movement Trace | ON |

## Results & Performance Evaluation

The performance of the proposed model namely, Message ferry route through cluster centers is evaluated on Dynamic Source Routing (DSR) protocol based on the number of ferry nodes and transmission range of the regular nodes in NS2 (Issariyakul & Hossain, 2012). For DSR protocol, different parameters like Packet Delivery Fraction (PDF), Average End-to-end Delay, Packets Sent, Packets Received, Packets Forwarded, Throughput, Normalized Routing Load (NRL) are calculated in different scenarios to solve connectivity problem in the partitioned MANET. The scenarios studied under simulation experiment are with no ferry node, 2 ferry nodes moving along a static path through 4 sub-centres of the grid, 1 ferry node following a dynamic path through the Cluster Centres, 2 ferry nodes following a dynamic path through the Cluster Centres, and the proposed MFR-CC Model in which 2 ferry nodes follow a dynamic path through the Cluster Centres with ferry nodes having a greater transmission range.

## A. Packet Delivery Fraction (PDF)

Packet Delivery Fraction (PDF) is the fraction of the total number of packets received successfully by the destination nodes to the quantity of packets transmitted by the source nodes during simulation.

$$\text{PDF} = \frac{\text{Number of Received Packets}}{\text{Number of Sent Packets}}$$

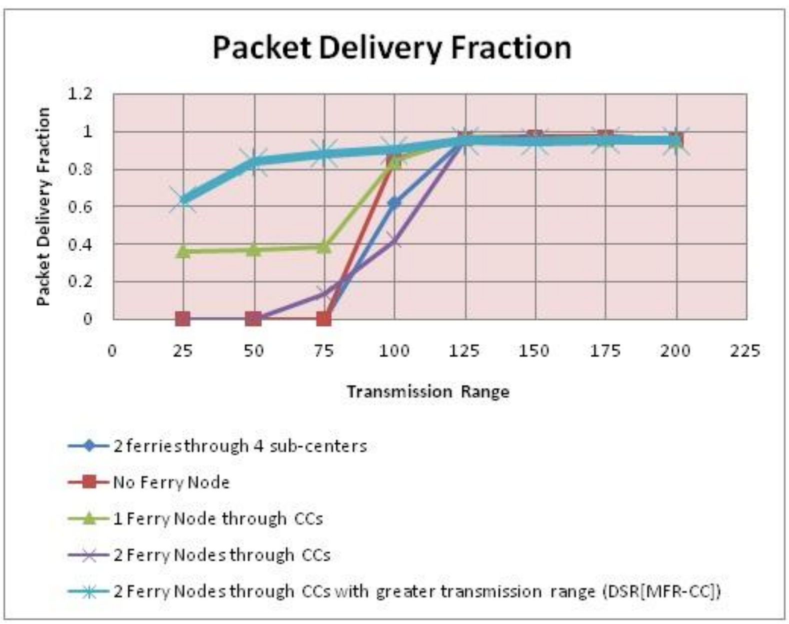


**Figure 5 PDF under different transmission ranges**

## B. Normalized Routing Load (NRL)

The Normalized Routing Load (NRL) is calculated as the ratio between the number of routing packets transmitted by the nodes to the quantity of packets actually received.

$$\text{NRL} = \frac{(\text{cp}_{\text{sent}} + \text{cp}_{\text{forw}}) * 100}{\text{Number of Data Packets Received}}$$

Where

$$cp_{sent} = r_{req} + r_{rep} + r_{err}$$
$$cp_{sent} = Control\ Packets\ Sent$$
$$cp_{forw} = Control\ Packets\ Forwarded$$
$$r_{req} = Route\ Request\ Packet$$
$$r_{rep} = Route\ Reply\ Packet$$
$$r_{err} = Route\ Error\ Packet$$

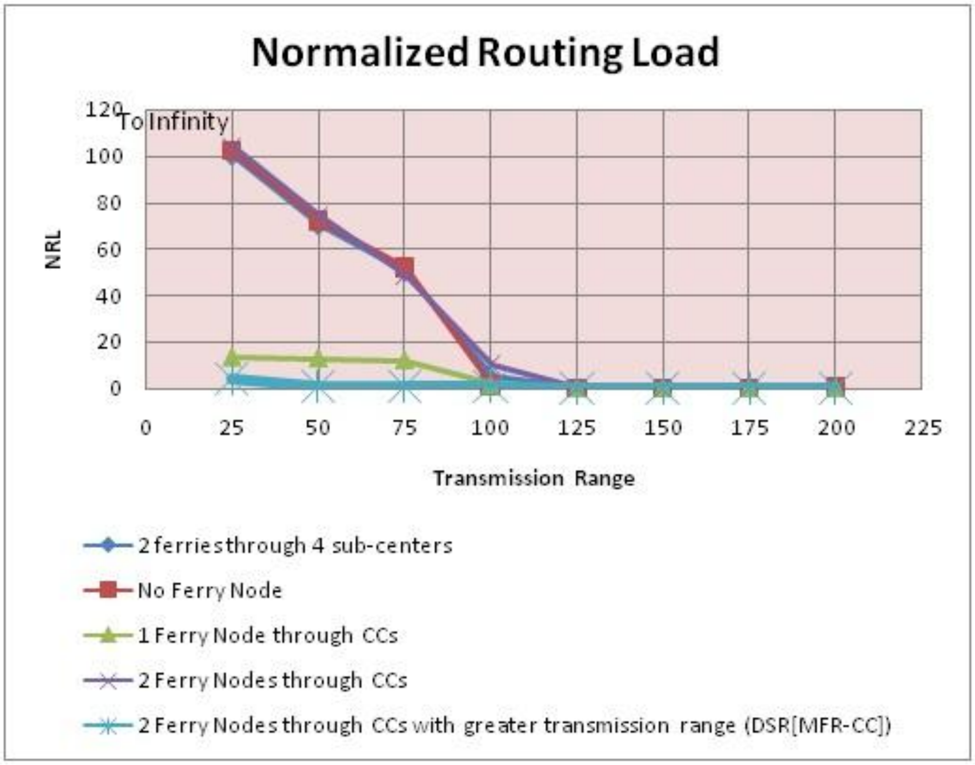


**Figure 6 NRL under different transmission ranges**

## C. Average end-to-end Delay (AED)

The Average End-to-end Delay (AED) is defined as the average time delay in the transmission and receiving of a data packet between two nodes and is calculated as follows

$$AED = \sum_{i=0}^{n} \frac{(\text{time}\{\text{Packet Recceived}\}_{\text{i}} - \text{time}\{\text{Packet Sent}\}_{\text{i}})}{\text{Total number of Packets Received}}$$

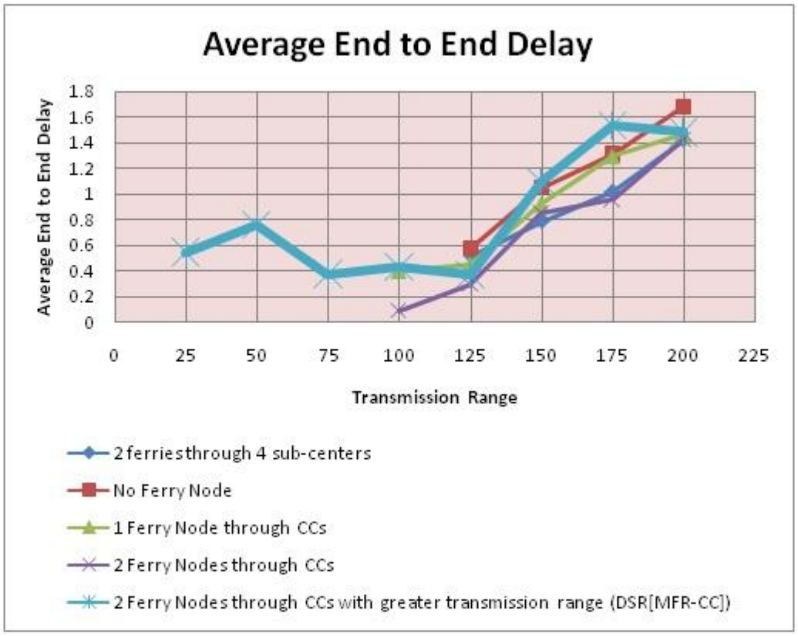


**Figure 7 AED under different transmission ranges**

## D. Throughput

The throughput of the routing protocol is the total size of useful packets that received at all the destination nodes at a particular moment or time-duration of the simulation. The measuring unit of throughput is MB/Sec.

$$\text{Throughput} = \frac{(\text{Number of sent bytes} - \text{Number of dropped bytes})}{\text{Simulation duration} * 1024}$$

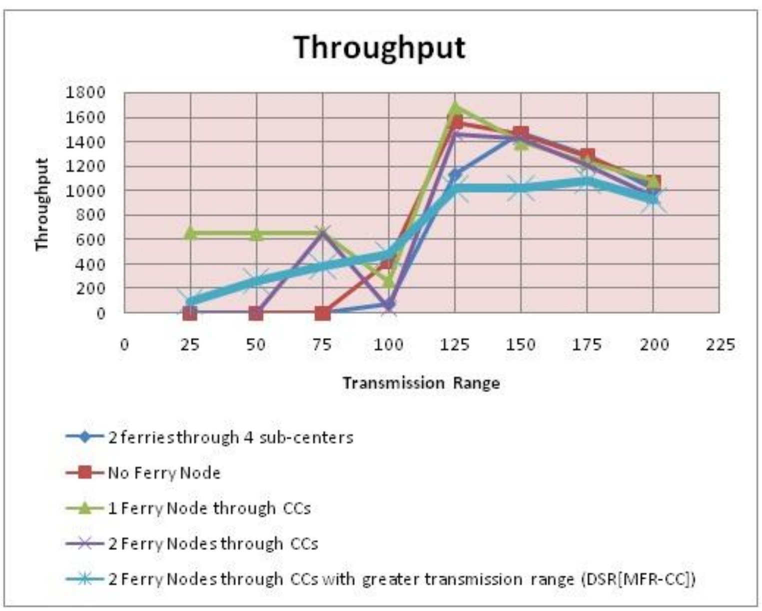


**Figure 8 Throughput under different transmission ranges**

## Conclusion

From the results, the proposed MFR-CC Model shows significantly better performance of the DSR protocol than the performance of other models, especially when the transmission range of the regular nodes is very less. From Figure 5 it is explicit that Packet Delivery Fraction (PDF) is 0 in most of the models, whereas MFR-CC model gives almost constant PDF irrespective of the transmission ranges of the regular nodes. Similarly, Figure 7 shows that at low transmission ranges the value of the Average End-to-end Delay is indeterminate in most of the models as the packets are not able to reach the destination but it gives a significant value in the proposed model. Figure 6 shows that the NRL value which represents the overhead of the control packets is nearly constant and very less, representing the success of the proposed model.

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