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DENSITY BASED GEOGRAPHICAL ROUTING IN INTERMITTENTLY CONNECTED MANETS

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ABSTRACT

MANET is a self-configuring infrastructure-less network of mobile devices connected by wireless medium. Each device in MANET moves independently in any direction and therefore changes its link to other devices frequently. IC-MANET is Intermittently Connected MANET in which there is no constant link between the end-to-end devices. Routing of packets through IC-MANET is a challenging job. LAROD, which is a geographical routing algorithm, enhanced with location service LoDiS is used to carry out routing efficiently in IC-MANETs. LAROD uses beaconless strategy for routing, whereas LoDiS maintains a local database of node locations which is updated often. The proposed work is to use the LAROD algorithm for routing and to overcome the drawbacks such as performance of the algorithm in very dense systems and to increase the speed of information dissemination, transfer of data using some compression algorithm and to reduce bandwidth.

Keywords- Delay-tolerant networks; node density; location service; mobile ad hoc networks (MANETs); intermittent connectivity.

I. INTRODUCTION

IC-MANETs are infrastructure less networks with an undefined network size. This nature of IC-MANETs allows any device to be attached to a certain network anytime. It is only limited by range of the wireless transmission. Thus, there are many problems and issues that need to be addressed for MANETs protocols. One of the main issues is the nodes movement and the dynamic change that occurs in the network topology. This study focuses on the operation of IC-MANET in an environment with varying network node densities, called heterogeneous density environment. Previous studies on node density have shown that MANET operation is very dependent on the availability of neighbour nodes.

ROUTING in infrastructure less network has received lot of attention in the last decade. The extent to mobile ad hoc networks (MANETs) and then carried over in the delay-tolerant networks (DTNs). Mobile Ad-Hoc Networks (MANETs) are an emerging technology that allows establishing instant communication infrastructures for civilian and military applications.

Tactical networks may choose to operate in an intermittent fashion for LPI/LPD reasons (low probability of interception and low probability of detection). Finally, deep space networks and underwater networks often have to deal with long propagation delay and/or intermittent connectivity. Conventional Internet routing protocols e.g., RIP and OSPF, as well as routing schemes for mobile ad hoc networks such as DSR, AODV, etc

LAROD is a geographical routing protocol which relies on location information of the nodes. LAROD needs to be supplemented by a location service that can provide the current physical location of the destination node for a packet. There have been many suggestions on how a location service can be provided in MANETs, but there have been no suggestions on how this service can be provided in an IC-MANET or DTN setting. The location dissemination service (LoDiS) is the first location service for IC-MANETs which disseminates node locations in the network using a Brownian gossip technique.

LAROD [3] is a geographical routing protocol which relies on position information of the nodes. LAROD needs to be supplemented by a location service [2] that can provide the current physical location of the destination node for a packet. A location service [7] can range from simple flooding-based services to hierarchical services. There have been many suggestions on how a location service can be provided in MANETs, but there have been no suggestions on how this service can be provided in an IC-MANET or DTN [5] setting. The location dissemination service (LoDiS) is the first location service for IC-MANETs which disseminates node locations in the network using a Brownian gossip technique [11].

LAROD-LoDiS routing algorithm handles intermittent connectivity but it is not suitable for systems with varying density (sparse and dense areas). For sparse systems, distribution of location information takes much time. For very large systems with thousands of nodes, the difficulty will be to distribute the location information to all the nodes in the system. The transfer of location information in such dense systems consumes much bandwidth of the network. In such scenarios, one can probably employ the density based techniques to overcome the density variation problem. The basic idea behind this technique is to detect the density of the network and defining the broadcast rate based on density.

In short, the problems identified in this study on IC-MANETs with varying node densities include: Low delivery

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ratio, low throughput and high end to end delay. D-LAROD is a density based probabilistic algorithm which is proposed to overcome the density variation problem [6] in IC-MANETs. The proposed algorithm will be neighbor aware and is expected to perform location information broadcast at rate which is determined by the density of the network. Thus, the algorithm performs less frequent broadcasting activities when there are a high number of neighbors around and will assume normal ree a high number of neighbors around and will assume normal broadcasting activities when the amount of neighbors are low. The broadcast rate varies with varying node
density.

Network node density

Density is one of the context parameter which influence the behavior of Ad-Hoc network. In network where node density increases, increasing the number of nodes in an area will result in congestion and collision. If nodes in an area is less, the coverage of nodes is very poor. Power consumption increase with increase density and vice versa.

Network node density can be differentiated into physical density and connectivity density. Physical density is number of nodes the coverage area of network. Connectivity density is number of nodes connected in the coverage area of network. Network physical density is considered as dense when large number nodes are in close proximity of one another within a particular area and vice versa for sparse. However, when determining the network density, one should also consider the connectivity of the network in terms of transmission range that covers the particular area. Thus, in this study, network density is based on the number of nodes found in a particular area and the connectivity of the nodes.

The node density impacts the routing evaluations since it determines, together with the mobility model, how many neighbors a node has. Below some threshold the network becomes so sparse that it is not longer possible to assume that the majority of nodes are connected any more. The average node degree is $\rho\pi R^2$ where ρ is the node density and R is the radio range. The average node degree is a dimensionless number and it enables us to compare the relative densities for evaluations using different radio ranges. The average node degree equals the average expected number of neighbors of a node.

The density of a network is defined based on the transmission range of the nodes as given below:

- The number of neighbors surrounding a node is denoted by its degree d
- A node with degree d = 0 is said to be isolated from the rest of the network
- dmin denotes the minimum degree of nodes and is considered as the smallest degree of all nodes in the network
- A network is said to be connected if there exists a path between every pair of nodes, otherwise it is disconnected
- A connected network always has a minimum degree dmin>0 but the reverse implication is not true
- A network is k-connected if for each pair of node exists k mutually independent paths connecting them

Density calculation: The density is calculated based on (1)-(3).

$$P(k\text{-con})\approx(1-e^{-\mu})^{n} \qquad (1)$$

$$\mu = \rho\times\pi\times r0^2 \qquad (2)$$

$$\rho = n/A \qquad (3)$$

where
P =Probability of the connectivity n = Neighbor count
A = Pre-defined area size ρ= density
π= 3.142
$r0^2$ = Transmission radius

In this study the value of k is set to1. This means for any particular network which has the probability of the connection of P(k-con)≥0.95 where k = 1, the network area is considered dense and there exists 1 mutually independent path connecting the nodes in the particular network area. Thus the network is mentioned as 1 -connected. This also implies that for any neighbors found within the transmission range of a particular node they are at most 2 hops away from each other. The node density of the network areas is calculated based on the formulae provided for P(k -con). Therefore an area is considered dense when a node identifies that:

- It neighbors are at most 2 hops away from it and it has a mutually exclusive path to other neighboring nodes that is independent of one another. Thus P(1-con)≥0.95

An area is considered sparse when nodes are isolated from a network or from one another:

- Nodes in sparse areas cannot guarantee at least a single connection in the network. Thus (P(1-con)≤

0.95)

- The minimal neighbor node degree for sparse areas could be dmin = 0. Thus, the node could be disconnected from the network

In the next section we present D-LAROD protocol. Section III, presents our evaluation of D-LAROD and compare the results with LAROD. Finally in section IV we end the paper with some conclusions and ideas on future work.

II. DENSITY BASED GEOGRAPHICAL ROUTING

This section describes the IC-MANET geographical routing protocol D-LAROD [4], followed by a description of the IC-MANET location service.

A. D-LAROD

D-LAROD is a geographical routing protocol for IC-MANETs that use greedy packet forwarding when possible. When greedy forwarding is not possible, the node that currently holds the packet (the custodian) waits until node mobility makes it possible to resume greedy forwarding.

It is a beaconless protocol that combines geographical routing

the store–carry–forward principle. A custodian forwards a message toward the destination by simply broadcasting it. All nodes within a predefined forwarding area are called tentative custodians and are eligible to forward the packet. All tentative custodians set a delay timer *td* specific for each node, and the node whose delay timer expires first is selected as the new custodian. The new custodian forwards the message in the same manner as the previous custodian. The old custodian that forwarded the message and other tentative custodians will overhear this broadcast and conclude that a new node has taken over custody of the packet. If the current custodian does not overhear any such broadcast within an interval of *tr* (rebroadcast time), it repeats the broadcast of the message until a new custodian becomes available due to node mobility.

It is also possible that all nodes in the forwarding area may not overhear the transmission made by the new custodian, thereby producing packet duplicates. This case will not only increase the load in the system but results in exploration of multiple paths toward the destination. When the paths of two copies cross, only one copy will continue to be forwarded.

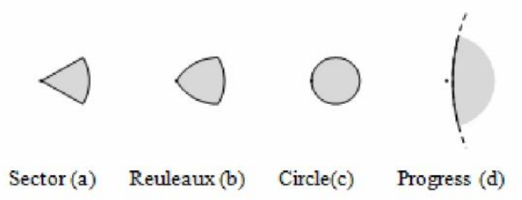

Figure 1. D-LAROD forwarding areas

When the time to live *tTTL* for a packet, which is expressed as duration, expires, a packet is deleted by its custodian. This is done to prevent a packet from indefinitely trying to find a path to its destination.

The forwarding area can have many shapes as shown in fig 1. Examples of shapes include a 60◦ circle sector, a Reuleaux, triangle, or a circle [Fig. 1(a) –(c)]. The longest distance between two points within these shapes must be the assumed radio range. If we want to maximize the probability of determining a new custodian, then the forwarding area should include all nodes that guarantee progress toward the destination [Fig. 1(d)]. In this paper, we have chosen progress forwarding area.

When a packet has been received by the destination, it sends an acknowledgement packet (ack) to stop further transmission of a packet by custodians and tentative custodians. All nodes that hear an acknowledgement will store the acknowledgement information until the packet times out. If a node receives a packet for which it previously has received an acknowledgement, then it broadcasts an acknowledgement packet to stop further transmission of the packet.

D-LAROD inquires the location service at each packet hop to overcome the inaccuracies of an IC-MANET location service, and if more recent position data are available, then the routed packet is updated. In this way, the location data is incrementally updated with accurate data as the packet approaches the destination. To still improve the quality of the location data in the location service, D-LAROD routing protocol provides it with the location data available in received packets. Fig. 2 shows the pseudocode for D-LAROD routing protocol.

B. Location Service

Due to the network partitioning of an IC-MANET environment, the information exchanged between the nodes can be delayed, which means that any time-dependent information that is received is more or less inaccurate. This indicates that any location service in an IC -MANET will generally provide inaccurate location data. This may be due to

Source node at data packet generation

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Get location data for destination from location service Broadcast data packet

Set up the timer for rebroadcast to tr
Destination node at data packet reception

If the packet is received for the first time
Deliver data packet to application
Broadcast ack packet

Else
Broadcast ack packet
All intermediate (non-destination) nodes at data packet reception

Update location service with location information of the data packet

//Packet has been received by the destination If an ack has been received for the packet

Broadcast ack packet
//The node is a tentative custodian If the node is the forwarding area

If the node has an active copy of the packet Set up timer for rebroadcast to td

Else
Do nothing Else

Remove active copy of the packet if it has one
At ack packet reception

Update location service with location information of the ack packet

If the node has an active copy of the packet Broadcast ack packet

Remove data packet Else

Do nothing
When a data packet rebroadcasting timer expires If the packet's TTL has expired

Remove packet Else

Update data packet's location information with location server data

Broadcast data packet
Set up the timer for rebroadcast to tr

Figure 2. D-LAROD pseudocode

For very large systems, the distribution of location information to all the nodes in the system would be a challenging task. If parts of the network become very dense, the transfer of location data may start to consume too much

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bandwidth locally at the dense spots. The time taken for a location update to reach the location server and/or the time taken for a location request to be answered by a location service. To avoid such delays, in location service, every node acts as a location server, and location updates are made by data exchanges as nodes encounter each other. The reason for treating all nodes as location servers is to avoid delaying the packet at the source node.

```
Calculate network density based on neighbor size
If network is dense
Broadcast location data with a random delay
Select location data vector with elements(node,
                location, timestamp)
Broadcast location data
Else
Broadcast location data without any delay

When a LoDiS broadcast is received
If the received location data is more recent
Update the entry in the LoDiS server

When the location data is received from the routing protocol
If the data received is more recent

Update the entry in the LoDiS server
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Figure 3. LoDiS Pseudocode

III. EVALUATION

In this section, we have shown the results from the evaluations of D-LAROD. The routing protocols have been evaluated in the network simulator ns-2. The D-LAROD scheme is compared with the existing geographical routing algorithm called LAROD and is shown to have a competitive edge, both in terms of delivery ratio and overhead. Delivery ratio and effort required for each generated data packet (overhead) are the two main evaluation metrics used. The delivery ratio determines the quality of service as perceived by the user or application and it is the most important evaluation criterion. The effort will be measured as the number of transmissions performed per generated data packet. Comparing the delivery ratio and overhead of D-LAROD with LAROD, a leading geographic delay tolerant routing scheme, we see that the benefit of using geographical information and active forwarding is very high.

Fig. 4 shows the impact of the packet lifetime on the delivery ratio. As shown, both routing protocols benefit from having more time to find a path from the source to the destination. The performance of D-LAROD is high compared to LAROD. This is because in D-LAROD, a random delay is introduced in dissemination of location data in dense networks which helps in freeing up of bandwidth at dense spots. Due to frequent node encounters, the protocols that actively forward the packets outperform protocols that rely on node mobility. As shown in fig. 5, the overhead for LAROD is about double that of D-LAROD.

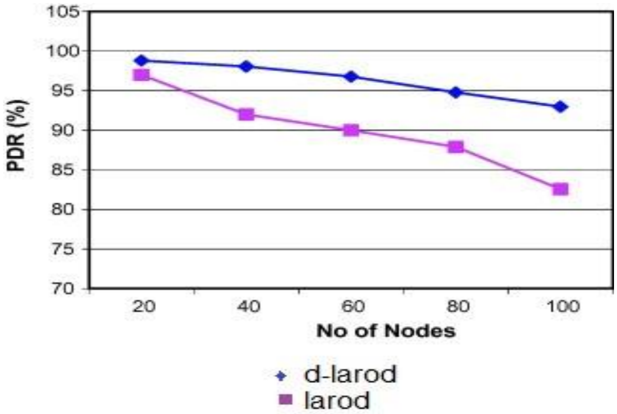

Figure 4. Packet lifetime vs delivery ratio

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IV. CONCLUSION

In this paper we identified a new class of dense and highly mobile networks not well addressed by conventional DTN or MANET approaches. We proposed a new Density based algorithm to the LAROD protocol that broadcasts the packets based on the density of the network. If it is low density network (sparse) normal broadcasts otherwise less broadcasts in case of dense network. It improved the performance of a simple DTN protocol. Simulations of our implementation in a dense and highly mobile network show significant performance improvements over regular Spray-and- Wait and LAROD-LoDiS.

Further studies can be done on very large systems where the challenge will be how the location information is distributed for all the nodes in the system. To do this approach, some kind of data compression or approximation methods for nodes located far away can be employed.

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