Density Based Geographical Routing in Intermittently Connected MANETs

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Abstract— **An Intermittently Connected Mobile Ad hoc Networks (IC-MANET) operates in environments where the nodes do not form a completely connected network. Existing geographical routing protocol like location-aware routing for delay-tolerant networks (LAROD) enhanced with a location service has shown to work well in IC-MANET. But the performance of this geographical routing protocol degrades with varying network node densities such as sparse and dense topologies. For sparse systems, distribution of location information will probably be very slow. For dense systems, the transfer of location data may start to consume too much bandwidth locally at the dense areas. In this work, we propose a density based geographical routing algorithm called density based location-aware routing for delay-tolerant networks (D-LAROD). D-LAROD calculates the density of the network based on which the dissemination of location data takes place. The D-LAROD scheme is compared with the existing LAROD protocol and is shown to have a competitive edge, both in terms of delivery ratio and overhead.**

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

I. Introduction

Intermittently connected mobile ad hoc networks (IC-MANET) are wireless networks where the nodes do not form a completely connected network. Instead, they will form connected partitions that changes their topology often. This kind of intermittent connectivity may happen when the network is quite sparse, in which case it can be viewed as a set of disconnected, time-varying clusters of nodes. Intermittently connected mobile ad hoc networks is a type of Delay Tolerant Networks (DTN) [1], that is, networks were incurred delays can be very large and unpredictable. There are many real networks that fall into this category. Examples include disaster scenarios and military operations, wildlife tracking and habitat monitoring sensor networks (IPN) etc.

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 neighbor nodes.

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 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 broadcasting activities when the amount of neighbors are low. The broadcast rate varies with varying node densities.

Node Density Issue

In real life situations it is not possible to have uniform sets of nodes populating the network area. Instead, different sets of nodes would be found scattered around the network area. This situation can be reflected in mobile network scenarios such as disaster areas, military applications and vehicular networks.

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 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
- d_{min} 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 $d_{min}>0$ 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).

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

$$\mu = \rho \times \pi \times r_0^2 \quad (2)$$

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

where
P =Probability of the connectivity
n = Neighbor count
A = Pre-defined area size
ρ = density
π = 3.142
r_0^2 = 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 d_{min} = 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 with 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 t_d 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 t_r (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.

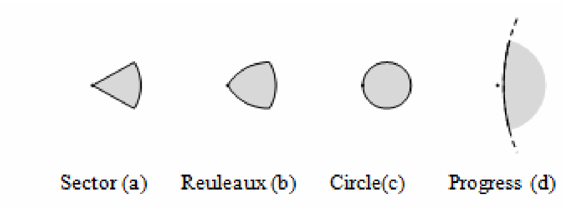

Figure 1. D-LAROD forwarding areas

When the time to live t_{TTL} 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 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.

```
Source node at data packet generation
   Get location data for destination from location service
   Broadcast data packet
   Set up the timer for rebroadcast to t_r

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 t_d
     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 t_r
```

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 bandwidth locally at the dense spots. The following consequences occur in networks with varying densities:

- Nodes in dense areas will flood the network with location information resulting in consumption of network bandwidth and decreased delivery ratio
- High packet loss due to location data dissemination by nodes in the dense network
- Location information would consume the bandwidth usage rather than data transmission

To overcome the network density variation problem in IC-MANETs, location service calculates the network density before disseminating the location information using (1-3). If the network is dense a random amount of delay is introduced. In sparse networks no delay is introduced and the location data is forwarded. Thus, the algorithm is expected to perform less frequent broadcasting activities when there are a high number of neighbors around and will assume normal broadcasting activities when the amount of neighbors are low. The pseudocode for LoDiS is shown in Fig.3.

When the routing protocol requests a location from the location service, the location data provided may be wrong due to the mobility of the nodes, but if the provided location points the data packet in the approximate right direction, it should be possible to use it as an initial estimate. To limit the location error, the geographical routing protocol should update the packet's location information for each node that the packet traverses. This is carried out by inquiring the node's local location server whether it has more accurate location information for the destination. This is based on the fact that nodes closer to the destination should have correct information on the destination's location. Thus the accuracy of the destination location is incrementally increased.

Location service is built on the conceptual solution used by SLS. A location server periodically broadcasts the information it has in its location table. Any node receiving this broadcast compares the information with the one it has, and the most recent information will be propagated when that node makes its broadcast. In this way, the location information is distributed throughout the network.

```
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
```

Figure 3. LoDiS Pseudocode

In addition to this, the geographical routing protocol provides the location service with location information present in the packet that it routes, which helps to improve the data in the location service.

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 (see Figs. 4 and 5).

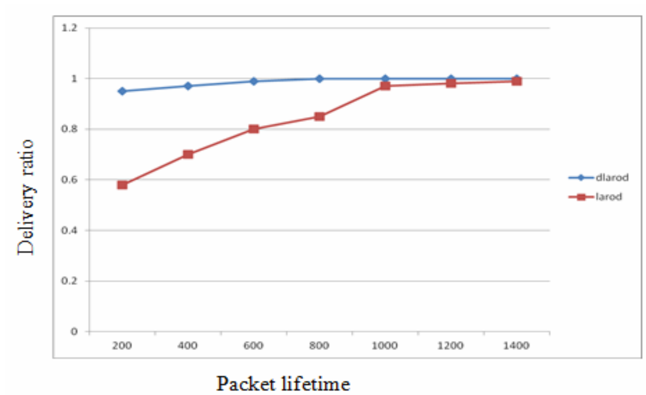

Figure 4. Packet lifetime Vs Delivery Ratio

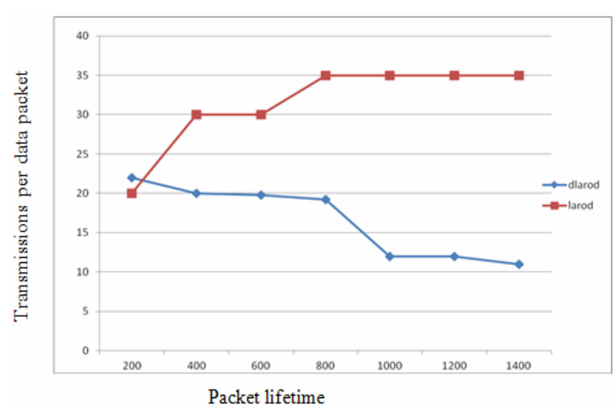

Figure 5. Packet lifetime Vs Transmissions per data packet

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.

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.

REFERENCES

[1] F. Warthman, Delay-Tolerant Networks (DTNs): A Tutorial v1.1. Warthman Assoc., Mar. 2003. [Online]. Available: http://www.dtnrg.org/docs/tutorials/warthman-1.1.pdf

[2] S. M. Das, H. Pucha, and Y. C. Hu, “Performance comparison of scalable location services for geographic ad hoc routing,” in *Proc. IEEE 24th Annu. Joint Conf. IEEE Comput. Commun. Soc.*, 2005, pp. 1228–1239.

[3] E. Kuiper and S. Nadjm-Tehrani, “Geographical routing in intermittently connected ad hoc networks,” in Proc. 1st IEEE Int.Workshop Opportunistic *Netw.*, 2008, pp. 1690–1695.

[4] T. Spyropoulos, K. Psounis, and C. S. Raghavendra, “Spray and wait: An efficient routing scheme for intermittently connected mobile networks,” in Proc. ACM SIGCOMM Workshop Delay-Tolerant Netw., 2005, pp. 252–259.

[5] V. Cerf, S. Burleigh, A. Hooke, L. Torgerson, R. Durst, K. Scott, K. Fall, and H.Weiss, Delay-tolerant networking architecture. RFC 4838. [Online]. Available: ftp://ftp.rfc-editor.org/in-notes/rfc4838.txt

[6] R. Bruno and M. Nurchis, “Survey on diversity-based routing in wireless mesh networks: Challenges and solutions,” *Comput. Commun.*, vol. 33, no. 3, pp. 269–282, Feb. 2010.

[7] T. Camp, J. Boleng, and L. Wilcox, “Location information services in mobile ad hoc networks,” in *Proc. IEEE Int. Conf. Commun.*, 2002, pp. 3318–3324.

[8] R. R. Choudhury, “Brownian gossip: Exploiting node mobility to diffuse information in ad hoc networks,” in Proc. Int. Conf. Collaborative Comput.: *Netw., Appl. Worksharing*, 2005, pp. 1–5.