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A Routing Protocol for Distributed Clustering in DTMNs

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Abstract: **A mobile ad-hoc network (MANET) is a self-configuring infrastructure less network of mobile devices connected by wireless links. The nodes are free to move about and organize themselves into a network. These nodes change position frequently. Routing in Intermittent networks can be improved by using the concept of clustering. Clustering basically deals with grouping of nodes into a group called as a cluster. By using the concept of clustering, we can reduce the overhead on a node of keeping its routing table up to date always and keeping track of the nodes that are around it. Here, we divide the implementation into two main parts: Intra and Inter-cluster routing. Intra-cluster routing deals with routing within the same cluster. Inter-cluster routing deals with routing between clusters. In intra-cluster routing, we just check whether the nodes in the path to the destination are connected. If they are, the message is routed in the designated path. If not, routing fails. The second part is to implement a routing protocol for a static Delay-Tolerant Mobile Network (DTMN) for Inter-cluster routing. The basic idea is to group a specific number of nodes into a cluster, initialize the Cluster-head and the Gateway. Perform Secure-cluster Routing to show that the sender should notify the cluster-head; that the message is being sent so that unauthorized nodes cannot send packets to a node of a particular cluster without the cluster head of the cluster knowing it. By this, the protocol helps in knowing what packet is being sent to which node. Compared the proposed protocol with the Direct delivery protocol considering time taken to deliver the message as a metric and the simulation results shows that proposed protocol takes less time.**

I. INTRODUCTION

DTN is fundamentally an intermittent network, where the communication links only exist temporarily, rendering it impossible to establish end-to-end connections for data delivery.Delay Tolerant Networking (DTN) is a new area of research in the field of networking that deals with extending existing protocols or inventing new ones in a coordinated, architecturally clean fashion, to improve network communication when connectivity is periodic, intermittent and/or prone to disruptions and when multiple heterogeneous underlying networks may need to be utilized to effect data transfers.The challenges of this field of research are:

1. Large delays (due to physical distances, small bandwidth, or extended disconnection).
2. A second challenge is efficient routing in the presence of frequently disconnected, pre-scheduled, or opportunistic link availability.
3. A third challenge is high link-error rates that make end-to-end reliability difficult.

Finally, heterogeneous underlying network technologies (including non-IP-based internetworks) and application structure and security mechanisms capable of limiting network access prior to data transit are required in environments where feedback may be highly limited.

A. Nodes In A Delay-Tolerant Network

In a DTN, a node is an entity with a bundle layer. A node may be a host, router, or gateway (or some combination) acting as a source, destination, or forwarder of bundles:

• Host—Sends and/or receives bundles, but does not forward them. A host can be a source or destination of a bundle transfer. The bundle layers of hosts that operate over long-delay links require persistent storage in which to queue bundles until outbound links are available. Hosts may optionally support custody transfers.

• Router—Forwards bundles within a single DTN region and may optionally be a host. The bundle layers of routers that operate over long-delay links require persistent storage in which to queue bundles until outbound links are available. Routers may optionally support custody transfers.

• Gateway—Forwards bundles between two or more DTN regions and may optionally be a host.

B. Scalable Routing In Dtns

Instead of routing with global contact knowledge, a simplified DTN model and a routing algorithm is proposed which routes on contact information compressed by three combined methods. The proposed algorithm, DTN Hierarchical Routing (DHR), approximates that of the optimal time-space Djikstra's algorithm in terms of delay and hop-count. At the same time, the per node storage overhead is reduced and becomes scalable. The DTN is modelled as a graph where vertices are nodes and edges are sets of (representative) contacts. This model allows only static nodes and nodes with strict repetitive motions. A strict repetitive motion means that the node moves on a predetermined trajectory repetitively and the position of the node is a function of time in each repetition.

C. Cross-Layer Protocol For Delay/Fault-Tolerant Mobile Sensor Networks

This protocol mainly addresses the trade-off between link utilization and energy efficiency. It includes 2 important phases, i.e., the asynchronous phase and the synchronous phase. In the first phase, the sender contacts its neighbours to identify a set of appropriate receivers. Since no central control exists, the communication in the first phase is contention-based. In the second phase, the sender gains channel control and multicasts its data message to the receivers. Furthermore, several optimization issues in these two phases are identified, with solutions provided to reduce the collision probability and to balance between link utilization.

D. Concept Of A Cluster

Clustering is grouping of nodes based on a similar pattern or a property such as location, priority etc. The word "cluster" is used broadly in computer networking to refer to a number of different implementations of shared computing resources. Typically, a cluster integrates the resources of two or more computing devices together for some common purpose.Clustering is grouping of nodes based on a similar pattern or property like the location, priority etc. Efficient cluster formation will be the crux of a routing protocol of this nature.Clustering in DTMN is unique and non-trivial, because of its intermittent connectivity. Although it is well learned that clustering can add more unique colours in to the routing technique, no previous work has been done in such emerging unique networks. Clustered networks are special type of networks, which can provide various innovative ways of looking at them in each individual's perspective.Our research is the effort to investigate the clustering problem and routing protocol for a clustered network.

In our research, we divided our vision in two directions as,

- Intra-cluster routing – *Within the cluster*
- Inter-cluster routing – *Between clusters*

II. PROPOSED WORK

Routing in DTMN is unique and non-trivial, because the network is not fully connected. Due to the lack of continuous communications, mobile nodes may have inconsistent information and therefore respond differently. As a result, it becomes challenging to acquire necessary information to form clusters and ensure their convergence and stability. A cluster head is elected for each cluster to maintain cluster membership information. Inter-cluster routes are discovered dynamically using the cluster membership information kept at each cluster head. By clustering nodes into groups, the protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process as well.

a. Routing Protocol For Clustered Networks

Challenges and tactics:

• Firstly and most importantly, MANET has a dynamically changing topology due to the movement of mobile nodes which favours routing protocols that dynamically discover routes (e.g. Dynamic Source Routing, TORA, ABR etc.) over conventional distance vector routing protocols. Secondly, the fact that MANET lacks any structure makes IP sub-netting inefficient.

• Secondly, the fact that MANET lacks any structure makes IP sub-netting inefficient. However, routing protocols that are flat, i.e. have no hierarchy, might suffer from excessive overhead when scaled up.

• Thirdly, links in mobile networks could be asymmetric at times. If a routing protocol relies only on bi-directional links, the size and connectivity of the network may be severely limited; in other words, a protocol that makes use of unidirectional links can significantly reduce network partitions and improve routing performance.Clusters are introduced to minimize updating overhead during topology change. However, the overhead for maintaining up-to-date information about the whole network's cluster membership and inter-cluster routing information at each and every node in order to route a packet is considerable. As network topology changes from time to time due to node movement, the effort to maintain such up-to- date information is expensive and rarely justified as such global cluster membership information is obsolete long before they are used.

b. Intra-Cluster Routing

In case of intra-cluster routing, the devices would be able to directly send the information (since the communication is within the cluster). This is also called direct routing. In hierarchical routing protocols, intra-cluster (inter-cluster) routing refers to the routing algorithm used to find a route between a source and destination within the same (belonging to different) clusters. Typically, intra-cluster routing is proactive.

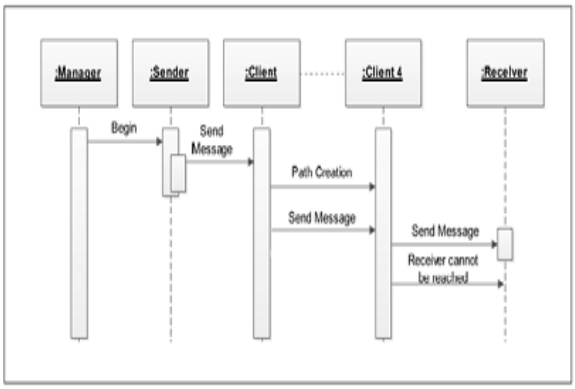

Fig.1. Sequence for Intra-cluster Routing

First, the Manager is initialized or started. Once the Manager node is started, it starts listening to the clients for their requests to join or leave the cluster. Once the clients have informed the Manager about their presence or absence in the cluster, the Sender mobile would be ready to send the message. Two clients, namely Client 1 and Client 3 have been given a chance of either entering or leaving the cluster. Once their choice is read, the Sender sends the message. Also, a path to the destination is created by the receiver client.

The message sent would be forwarded to the nearest client in the cluster. The client who receives the message would forward it to the next client according to the path created. If the Receiver cannot be reached, the message cannot be sent.

c. Inter-Cluster Routing

In case if inter-cluster routing, the routing should happen through multiple clusters, i.e. communicating nodes might be of different clusters. Inter-cluster routes are discovered

dynamically using the cluster membership information kept at each cluster head. By clustering nodes into groups, the protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process as well. Furthermore, the protocol takes into consideration of the existence of unidirectional links and uses these links for both intra-cluster and inter-cluster routing.

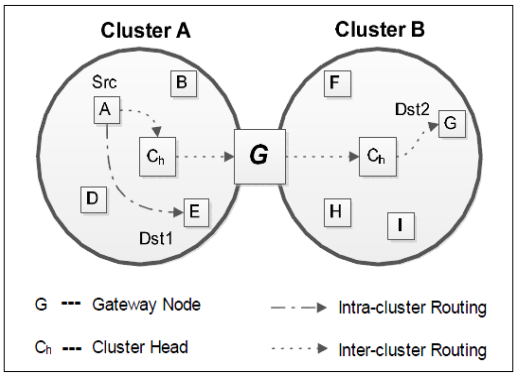

Fig.2. Intra and Inter-cluster Routing repesentation

The above diagram depicts the concept of Intra and Inter Cluster Routing. Here, a node "A" from cluster A wants to send data to a node "E" in the same cluster. The message can be directly routed to E without the help of the cluster head as every node has information about every other node in the same cluster. Also, node "A" wants to send data to node "G" of cluster B. To route the message, node "A" sends the message to its cluster head C_h. The cluster head forwards it to the gateway node which then sends it to the cluster head of the cluster B. Cluster head of B routes the message to the appropriate node in its cluster (in this case node "G").

d. Selection Of Cluster Head

A cluster head is elected in the cluster formation process for each cluster. Each cluster should have one and only one cluster head. A cluster head has complete knowledge about group membership and link state information in the cluster within a bounded time once the topology within a cluster stabilizes. In CBRP, each node in the cluster has a bi-directional link to the cluster head.Conceptually, two cluster heads are not allowed to have a direct bi- directional link to each other. If such a link exists, one of the cluster head will relinquish its role as cluster head to the other. However in CBRP, we can allow two cluster heads to be able to hear each other directly for CONTENTION_PERIOD seconds before one cluster head has to give up its cluster head status; this delay postpones any cluster re-organization, in case the two clusters are next to each other only in passing.

The cluster head can be selected as follows:

a) Each node calculates its absolute priority.
b) A node without a neighbouring cluster head declares itself a Cluster head if it has the largest absolute priority among its neighbours that haven't joined any cluster.
c) A node having neighbouring cluster heads chooses one with the largest relative priority and joins that cluster.

A node is called a gateway node of a cluster if it knows that it has a bi-directional or unidirectional link to a node from another cluster. Any node a cluster head may use to communicate with an adjacent cluster is called a gateway node.

By Gateway Discovery, a cluster head for cluster X will obtain the information about cluster X's bi-directionally and upstream uni-directionally linked neighbouring clusters.For this purpose, a Cluster Adjacency table is kept at each node which is formatted as follows:

Adjacent Cluster1	adjacent node	to/from/bi
Adjacent Cluster2	adjacent node	to/from/bi
...		

Fig.3. Adjacency Table

By Gateway Discovery, a cluster head for cluster X will obtain the information about cluster X's bi-directionally and upstream uni-directionally linked neighboring clusters.

This table is updated by the periodic HELLO message a node hears. Note that a node may have several links to nodes in a particular cluster and only one of them is recorded in the Cluster Adjacency Table.

The selection rule is as follows:

1. A bi-directional link takes precedence over all uni-directional links.
2. Of the links that have the same precedence, the one with the highest absolute priority wins.

This table is periodically sent to the member node's host cluster heads. (It could be piggybacked to the HELLO message if possible.) A cluster head uses its members' Cluster Adjacency table to construct its own cluster adjacency table.The construction rule is the same as that of the member's.

Cluster head will flood its neighboring clusters with a message of TTL 3 in search for the "to" link that corresponds to a "from" link in its Cluster Adjacency Table. As a result, cluster heads will have complete knowledge of all its bi-directionally linked neighboring clusters even if there is no actual bi-directional links in between.

We represent the design of the inter-cluster routing as a pseudo code as in Fig. 4 . Here, when a node recieves a message, it finds the nearest neighbour and sends the message to the neighbour node with the help of the cluster-head. Then, this neighbour node acts as a new source and this process continues till the message reaches the destination node. A node intimating the cluster-head while sending the message to other node is the uniqueness in this routing protocol.

```
findRoute (src-> destn)
begin
    if (src=destn)
        return;
    Find distance between all the nodes.
    As long as Destination is not reached
    begin
        a. Identify neighbours for src and find path
        b. If a neighbour is found, increment "neighbourCount"
        c. If neighbourCount > 0,
           If neighbour is itself destination, break.
              ⇒ Find next neighbour.
              ⇒ Send data to next neighbor along with intimating
                the cluster-Head.
              ⇒ Make this neighbour as source.
        end
end
```

Fig.4. Inter-cluster Routing algorithm

III. SIMULATION

a. Intra-Cluster Routing

In case of intra-cluster routing, the devices would be able to directly send the information (since the communication is within the cluster).Because DTN is intermittent, there is always a possibility of the connecting nodes of the cluster going out of range, causing the other mobile nodes to be disconnected.
Network manager or the cluster-head begins to listen to all the clients i.e. manager is ready to accept requests from clients. The clients or the nodes can request for and also accept connections from other clients and all clients will be controlled by the cluster-head.

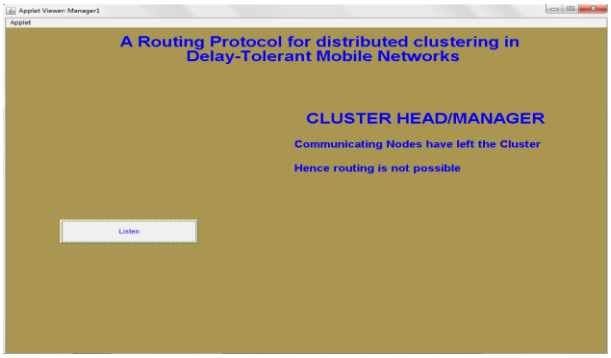

Fig.5. Intra-cluster Routing Initial Phase

With all the nodes in the cluster and after the synchronization phase, the wireless devices connected to the clients can easily transmit information among each other.

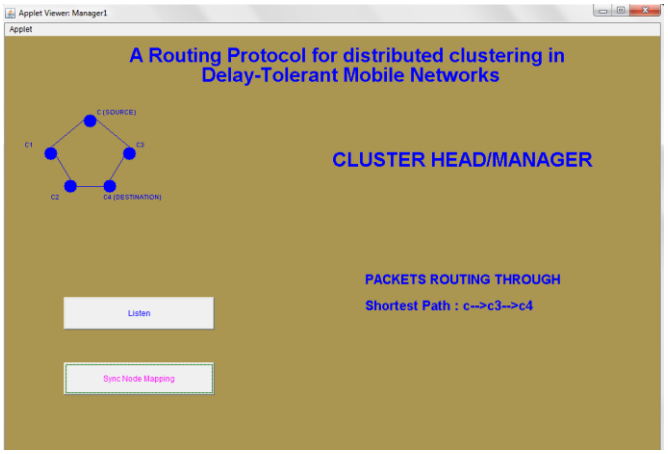

Fig.6. Intra-cluster Routing Final Phase

b. Inter-Cluster Routing

Here the routing should happen through multiple clusters, i.e. communicating nodes might be of different clusters.
We have used a protocol Direct- Delivery protocol, to compare with our proposed protocol.In, Direct-Delivery protocol, the wireless nodes communicates using the transmission ranges of the neighbouring nodes.

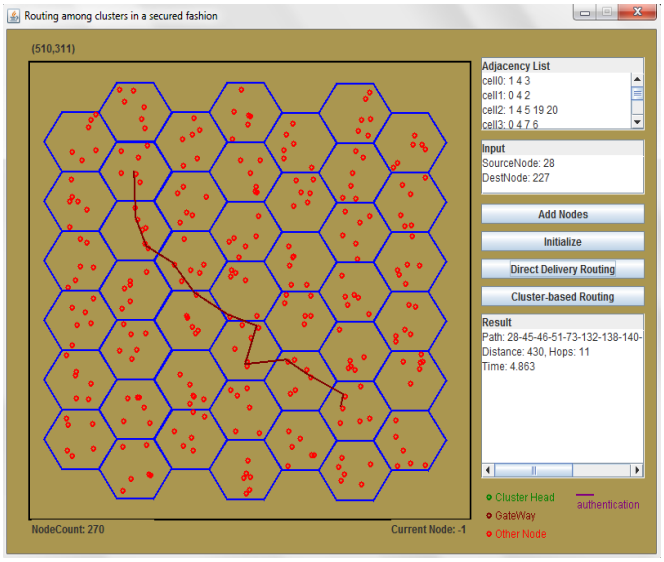

Fig.6. Direct Delivery Routing

However, with the clustering of the wireless networks and there might be some delay in grouping nodes and selecting cluster-head and gateway.
As one can infer, a node from a cluster before sending the information to the other node which is in its transmission range (neighbor), it intimates the cluster head of the cluster, which in turn would have the information about the other nodes and thus would help in the routing of the message. On comparing Direct Delivery and the cluster based routing protocols' time taken for a node to send the message to the destination – Direct Delivery routing takes 4.863 => this is the time for source to send information to the destination node.

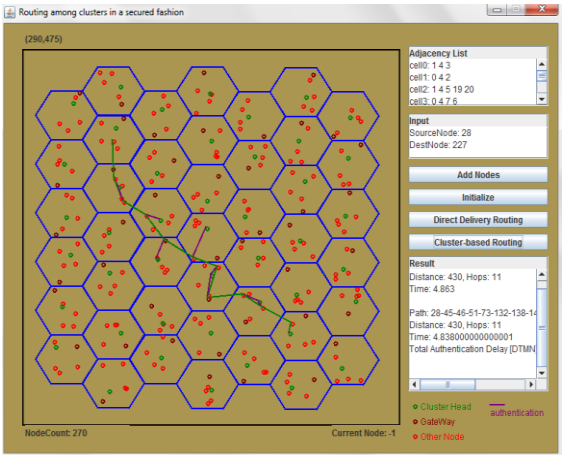

Fig.7. Inter-cluster Routing

Cluster-Based routing - 4.838000000000001 => this time includes time taken for the node to send the information to the destination and the authentication delay - 3.4639999999999986 ,where this authentication delay is the time taken by the nodes to intimate the their cluster-heads that they are sending messages to other nodes of the cluster. Thus, the clustering approach has an upper hand over the non-clustering approach.

IV. CONCLUSION

We were effectively able to visualize and simulate both the intra-cluster routing (routing with-in cluster) and inter-cluster routing (routing between clusters).We also observed how the intermittent characteristic of the Delay Tolerant Network can affect routing of messages and the importance of the routing table that each node maintains, which is used while making routing decisions according to the store-carry-forward paradigm.It is also evident that the selection of a cluster-head and a gateway for a cluster becomes easy when a static instance of the Delay Tolerant Mobile Network is considered. As noticed, a cluster-head was selected based on the nearest node or the point at the centroid and gateway as the farthest point from the centroid of the cluster boundary. Hence, we can jump in to a conclusion that when a network, being a delay tolerant network or any other network, realization of these networks as graphs makes solving any problem or performing any operation on these networks such as node counting, routing etc. easy.With the reference of the inter-cluster routing analysis, we saw though authentication of a node with a cluster-head was at a slight non-negligible cost, we cannot take chance by allowing the nodes to communicate without any authentication, as the network is wireless, any node (say, malicious) can join a cluster or intercept the transmission range of other valid nodes and then can transmit its' information. Thus, authentication is also as important as routing.

As a future-work, since all our work was based on a static instance of the Delay Tolerant Network, it has to be extended to dynamic networks in future in-order to gain a better conclusion. Also, based on this dynamic movement of nodes, cluster-head and gateway node has to be selected accordingly, and routing of messages should take place.

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