Distributed Mobile Servers: Vehicle to Increase Effective Bandwidth and End to End Connectivity in an Adhoc Mobile Network

Hridesh Rajan
hridesh@ieee.org

Abstract

Distributed Mobile Server is a novel concept to increase the available bandwidth and end to end connectivity in an Adhoc Mobile Network. Adhoc Mobile Networks are best option as far as easy deployment and configuration is concerned, but they do not scale well due to amount of overhead involved with forwarding and updating done at mobile nodes. A partition of such network into smaller networks connected using backbones can lead to better performance in terms of utilization of bandwidth and lead to the savings in battery power at the mobile nodes up to some extent. If the partition is done statically, like the typical fixed networks, utilization of the available resources is mostly sub-optimal. The backbone, typically a fixed network, will also defeat the underlying principle of easy deployment. Providing a set of mobile servers, which co-operate with each other to cater to the need of bandwidth while maintaining the philosophy of easy deployment, can solve the problem. This paper describes the concept of Distributed Mobile Server, which intelligently cater to the needs of the network, shifting their position according to the needs. This hierarchical approach helps in optimal utilization of the available resources, while conforming to the basic philosophy of easy deployment.

1. Introduction

Adhoc mobile networks are attracting a lot of attention these days due to little efforts needed to deploy them. These networks prove to be economical in sparse areas. In emergency services such as disaster recovery these networks are the only possible options. These networks are a valid substitution for local area networks as well. Nodes in an Adhoc Mobile Network forward packets to establish a virtual network backbone. The idea of forwarding each other's packets eliminates the need for a fixed network for communication. Zero configuration requirement is also an attractive point for Adhoc Mobile Network making it suitable for Home Networks or users who either don't know how to configure a network or don't have an inclination to do so.

The idea of packet forwarding although works well in the case of small network, as and when the network size increases each node has to devote a significant amount of computing power for forwarding other node's packets. In the coming time these networks will need to support multimedia traffic such as voice, video and data. To fulfill these requirements, networks carrying data in real time and having high throughput, low delay and fault tolerance are desired which can not be provided using existing methods. Another problem with Adhoc Mobile Networks is their inefficiency to deal with the node density. If a cell become crowded, bandwidth share of each node will decrease and workload on each of them will increase due to increase in number of packets to forward and location updates to be done. If node density in a cell drops too low the probability of a message encountering dead-ends of the network increases.

This approach tries to partition the network, as it grows, to make it more scalable. Among the two approaches to provide network connectivity in an Adhoc Mobile Network it insists on following the *hierarchical* network architecture implicitly in such a way as not to compromise the benefit of the *flat-routed* architecture. It incorporates the first in such a way that does not require the maintenance of the hierarchies. Partition of an Adhoc Mobile Network into smaller networks connected using backbones will result in decrease in number of packets forwarded by the mobile nodes for others. It can lead to better utilization of bandwidth and savings in battery power at the mobile nodes. It will also reduce the cost of location update in such networks. Congestion in the network also decreases, because most of the traffic long distance traffic is effectively carried by the backbone. Network utilization of the available resources is mostly sub-optimal in case of static backbones. The static nature of the backbone will also require prior efforts for deployment thus reducing the advantage of a Adhoc Mobile Network.

Distributed Mobile Server (DMS) can increase the Effective Bandwidth and End to End connectivity in an Adhoc Mobile Network. It acts as virtual backbones for the mobile nodes. It provides the mobile nodes a point of connectivity much like a gateway to the Internet. It aims to do so using intelligent monitoring of mobile nodes and changing its geographic location according to the needs of the mobile nodes. The group of DMS interacts with each other to share a common understanding of the system. With the movement of the nodes the node density of cells changes. The group of DMS then reorganize themselves to cater to the needs of the changing environment. By reorganizing themselves, they effectively change the architecture of the virtual backbone resulting in increase/decrease in the available bandwidth in some areas according to the needs. Using geographic location and routing mechanism it eliminates the need for creating and maintaining hierarchies. Mobile nodes are automatically associated with the DMS closest to them and as they leave an area covered by the DMS their affiliation changes.

DMS approach does not compromises any of the objectives stated for Adhoc Mobile Networks routing protocols in [7]. It does not depend on any fixed infrastructure for its deployment. In addition it can overcome some of the constraints of the mobile networks. It will reduce the bandwidth constraint to an extent. It will also reduce the energy consumption of mobile nodes. Having a reliable node in the form of DMS in vicinity can also be used as means to provide secure services over Adhoc Mobile Networks. It will act as a shock absorber for changes in the topology of the network, thus reducing the overhead of topology updating to some extent.

Rest of the paper describes the Issues in the design of a Distributed Mobile Server. Section 2 establishes the need for a virtual backbone for Adhoc Mobile Networks. Section 3 describes the issues related to load balancing in DMS, positioning of DMS and their movement. Section 4 explains the working of DMS by fitting it into some of the existing Adhoc Mobile Network routing algorithms and section 5 concludes.

2. Virtual Backbone

A typical network backbone is like a static tree where each branch has fixed bandwidth. Usually depending on the number of users in a sub network a fixed capacity backbone network is provided to connect the sub-network to other sub-network or Internet. Depending on the size of the network they are allotted fixed links to communicate with each other and change in the bandwidth of these links is neither easy nor cheap. Scenario in the case of a mobile network is quite different. The bandwidth requirements in different cells of a mobile network may vary with time as a result of the motion of the mobile users, which is unpredictable.

It may happen that some cells, where typical bandwidth requirement is close to zero most of the time, become a hot spot. A cell containing a stadium is the example of such a cell. Density of mobile user in the cell is close to zero most of the time, but may increase to more than the user density at a busy mall, while a popular game is going on. It may also happens that a cell which is a hotspot for a long time, the user density there plummets to very low value during some hours.

As the node density increases the effort required by the nodes to forward other node's packets increases and there share of the radio spectrum decreases. To alleviate this problem a fixed network can be applied as suggested. But this defeats the purpose of Adhoc Mobile Network i.e. easy and no effort deployment. A set of DMS can form a virtual backbone network, which can be deployed without any effort. The capacity of any branch of this network varies with the node density at the sub-network connected to it. In the case of increase in node density more number of DMS can be moved to the place to cater to the need of the subscribers over there and vice-versa for decrease in the node density. This virtual backbone does not require any changes in the geographic routing methods and appear to the other nodes as just another mobile node. As inferred in [1] probability of dropping packets and packets reaching dead end decreases with decrease in the number of hops and increase in transmission radius. In virtual backbones both of them are achieved. Increase in transmission radius is achieved by DMS transmitting with high power transmitters and decrease in number of hops is achieved by transmitting the message using the virtual backbone instead of through a large number of mobile nodes having small transmission radius.

3. Distributed Mobile Servers

Some of the issues that will be important while incorporating this approach in the existing routing algorithm for Adhoc Mobile Network are described in the following subsections.

3.1 Load Balancing

Load balancing is an important consideration in the implementation of DMS. If the load is not evenly balanced it may result in the congestion on the virtual backbone, which will defeat its purpose altogether. Fault tolerance must be taken care of while selecting an appropriate algorithm for load balancing. If DMS catering to the need of an area is not responding it must provide backup DMS to take its place dynamically otherwise the nodes of those areas will be isolated. Specifically a load balancing system should detect errors and reroute traffic automatically by actively querying DMS. It should degrade gracefully as opposed to sudden collapse. The load balancing system should also be able to detect deployment of a new DMS and should be able to configure new DMS without any manual intervention. Further the load balancing system must itself be distributed.

Another key requirement to assure high availability is to offer functionality known as traffic prioritization. This enables the virtual backbone to allow varying access services levels based on traffic source, type and destination- guaranteeing access.

3.2. Positioning of DMS

Positioning of DMS will also affect the performance of the virtual backbone. The positioning of the DMS will require information from the GPS [4] and it will learn information about the local terrain where the system will be operating from experience. The positioning of DMS will determine the jurisdiction of mobile nodes it will cover. Jurisdictions will also depend upon physical factors like obstruction or emergency needs like failure of a DMS etc. The covering area is divided into jurisdiction and each DMS is allotted one area. The position of the DMS in the area is such that it remains in contact to at least two other DMS for redundancy purposes. An example position of a DMS system is shown in Fig 1. The shaded portion of the figure represents blocked areas. The mobile nodes are represented by black circles and DMS by squares. Arrows represent movement, dashed lines represent nodes within

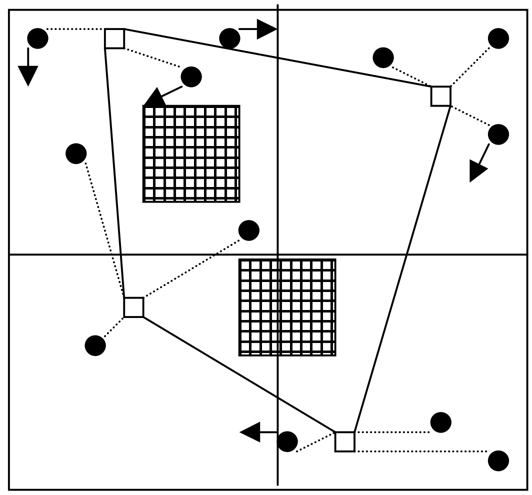

Fig. 1 Sample positioning of DMS

the jurisdiction of a DMS and solid lines represents communication path of two DMS.

3.3 Movement of DMS

A DMS system should reorganizes itself according to the changing environment. As the node density in jurisdiction/s fluctuates, jurisdictions should be adjusted to provide uniform service to all the nodes. A sample change in jurisdiction is shown in Fig.2. The DMS in the left-top quadrant had moved down to control new set of nodes and the DMS in the right-bottom quadrant had moved a bit right to come in the line of sight of the DMS in the left-top quadrant, while other DMS are stationary. The DMS in the right-top quadrant now establishes contact with the DMS in the left-bottom quadrant instead of previous left-top DMS, because it is out of line of sight. For the same reason DMS on the left-top contacts DMS on the right-bottom.

5. DMS in context of the present routing algorithms

Three routing algorithms are chosen to show how DMS fits in each of the approaches with least change required.

5.1. Zone Routing Protocol

This protocol [2] introduces concept of routing zones, which is defined for each node and include the nodes whose distance in hops are at some predefined number zone radius. Each node is required to know the topology of the network within its routing zone only and nodes are updated about topological changes only within its routing zone. For routing purpose it uses route discovery protocol which broadcasts the query to the nodes on the periphery of the

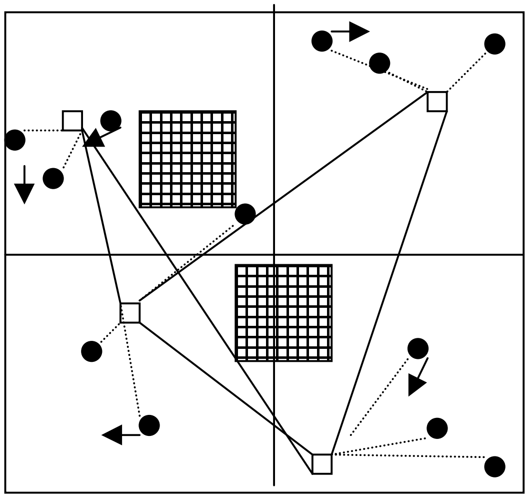

Fig. 4 Change in jurisdiction of DMS

routing zone. The peripheral nodes then forward the packet or return the route depending on their accessibility to the destination node. The forwarding is done up-to a maximum value called max-hop.

This algorithm can easily incorporate DMS by setting zone radius of each of the nodes to 1 and max-hop to 1. By setting these variables to one will ensure that packet will not be forwarded to the nodes in other DMS jurisdiction. Since a DMS is available within one hop of any node, it will receive all route discovery messages forwarded by the peripheral nodes, if it is not on periphery and it will reply to the query message after appending its identity in the message.

5.2. Distance Routing Effect Algorithm for Mobility

A proactive routing algorithm called DREAM [3] it keeps location information for any other node in the network. A node uses the GPS system [4] to obtain this information and later disseminates the information by exchanging location information between nodes. When a node needs to send a packet to a recipient node, it refers to its location table in order to retrieve location information about the recipient. Based on this information it selects from among its neighbors those nodes that are in the direction of recipient and forwards the packet to them. Each of the nodes in turn does the same, forwarding the packet to those nodes in the direction of recipient until, if possible, it is reached. This approach uses control packets to disseminate the location information. The control packets are of two types short lived and long lived. The short-lived packets are discarded after fewer hops whereas long lived packets travel a long way.

Since this system uses the geographic location to send packets it will select the DMS in the direction of the recipient over other node for forwarding packets because of the location update information by the DMS. The DMS in turn routes the packet to it destination through the virtual backbone. The control packets are not disseminated by the DMS. It uses them to update its own location tables.

5.3 Geographic Location Service

In this algorithm [5] and its implementation [6] each node determines its position using a mechanism such as GPS [4]. A node then announces its presence, position and velocity to its neighbors by broadcasting hello packets. Each node periodically broadcasts a list of all neighbors it can reach in one hop using a hello message. When a node receives a hello packet, it updates its local routing table with the hello message information. To select a next hop, nodes first choose a set of nodes from all nodes in their neighbor table. This list consists of the best nodes to move the packet to, as defined by the shortest distance to the destination. The packet is then forwarded to any one of those nodes

In this system much like DREAM, DMS sends the hello packets to all the nodes in its jurisdiction, which shows that all nodes except directly reachable nodes can be reached through DMS in shortest number of hops. As a result of such location information dissemination, location tables of all the nodes in a DMS jurisdiction contain entry of DMS for all nodes reachable in multiple hops. Being at a shortest distance then others nodes all multi-hop packets are send to the DMS that in turn routes them to the destination.

Some other systems were also analyzed and it was inferred that this approach fits with any routing protocol, whether reactive or proactive which uses Geographical hints to take routing decisions. The systems like [8], which implement routing protocols not based on Geographical location, but on the basis of logical topology are not compatible with this approach. Those network topologies are also difficult to establish in an Adhoc Mobile Networks.

Conclusion

This paper presented a new approach for increasing the available bandwidth and end to end connectivity in an Adhoc Mobile Network. Distributed Mobile Servers if used in conjunction with routing algorithms for Adhoc mobile networks can increase the Effective Bandwidth and End to End connectivity by manifold. This approach guarantees better performance in terms of throughput, low delays and fault-tolerance. In addition this approach works with almost all the proactive and reactive routing algorithms. However the mobility of DMS is a problem which hinders their deployment. The efficiency of this approach will depend on the choice of algorithm for load balancing, positioning and movement of DMS to satisfy the stated requirements.

References

[1] Z. J. Haas, "The Relaying Capability of the Reconfigurable Wireless Networks," VTC'97, Phoenix, AZ, May 4-7, 1997.

[2] Z.J. Haas, "The Routing Algorithm for the Reconfigurable Wireless Networks," *ICUPC'97*, San Diego, CA, October 12-16, 1997

[3] S. Basagni, I. Chlamtac, V. R. Syrotiuk, and B. A. Woodward. "A distance routing effect algorithm for mobility (DREAM)." In Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking, MobiCom'98, pages 76--84, Dallas, TX, October 25--30,1998.

[4] USCG Navigation Center GPS page, Sept, 2000 http://www.navcen.uscg.mil/gps/default.htm

[5] Jinyang Li, John Jannotti, Douglas S. J. De Couto, David R. Karger, Robert Morris, *A Scalable Location Service for Geographic Ad Hoc Routing*, ACM Mobicom 2000, Boston, MA.

[6] Robert Morris, John Jannotti, Frans Kaashoek, Jinyang Li, Douglas Decouto, *CarNet: A Scalable Ad Hoc Wireless Network System*, 9th ACM SIGOPS European Workshop, Kolding, Denmark, September 2000.

[7] S. Corson, J. Macker . Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations Request for Comments: 2501,Internet Engineering Task Force, January 1999 http://www.ietf.org/rfc/rfc2501.txt

[8] J. Sharony, An Architecture for Mobile Radio Networks with Dynamically Changing Topology Using Virtual Subnets, *ACM-MONET Mobile Networks and Applications*, Vol. 1, No. 1, pp. 75-86, 1996.