

Routing techniques for Mobile Ad Hoc Networks Classification and Qualitative/Quantitative Analysis

Mr. Ankur Khetrpal
Department of Computer Engineering
Delhi College of Engineering
Delhi University

Abstract - *Routing is a core problem in networks for delivering data from one node to another. Wireless Ad Hoc networks are also called Mobile Ad Hoc multihop wireless networks without predetermined topology or central control. In this paper I present a number of ways of classification or categorization of these routing protocols and did Qualitative / Quantitative analysis of a dozen typical existing routing protocols. In qualitative analysis I compare their properties according to different criteria and in Quantitative analysis I used a Simulator QualNet to study their relative performance according to different criteria.*

Keywords: Routing protocols, Mobile Ad hoc Networks

1. Introduction

Routing is a core problem in networks for delivering data from one node to another. Wireless ad Hoc networks are also called Mobile Ad Hoc multihop wireless networks without predetermined topology or central control. Mobile Ad Hoc Networks (MANETs) can be characterized as having a dynamic, multihop, potentially rapid changing topology. Such networks aim to provide communication capabilities to areas where limited or no communication infrastructures exist; or, where it is simply more convenient to allow the communication devices to form a dynamic and temporary network among them. Several routing protocols have been proposed for mobile ad hoc networks. A mobile ad-hoc network (MANET) [2] is usually formed by mobile nodes using wireless communications and receiving attention due to many potential military and civilian applications. A MANET uses peer-to-peer multi-hop routing instead of a static network infrastructure to provide network connectivity. MANETs have several salient characteristics: 1) *Dynamic topologies* 2) *Bandwidth-constrained, variable capacity links* 3) *Energy-constrained operation* 4) *Limited physical security*. Therefore the routing protocols for wired networks cannot be directly used for wireless networks. Some examples [2, 3] of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake. There have been several routing protocols proposed for wireless Ad Hoc networks. In this paper I present a number of ways of classification or categorization of these routing protocols and did Qualitative and Quantitative analysis of a dozen typical existing routing protocols. In qualitative analysis I compare their properties according to different criteria and in Quantitative analysis I used a Simulator QualNet to study their relative performance according to different criteria.

2. Classification

There are different criteria for designing and classifying routing protocols for wireless ad hoc networks. For example, what routing information is exchanged; when and how the routing information is exchanged, when and how routes are computed and so on. I will discuss these criteria in this section.

2.1 Proactive vs. Reactive Routing

Proactive Schemes determine the routes to various nodes in the network in advance, so that the route is already present whenever needed. Route Discovery overheads are large in such schemes as one has to discover all the routes. They consume bandwidth to keep routes up-to-date. Packet forwarding is faster in these schemes as the route

is already present. Examples of such schemes are the conventional routing schemes, Destination Sequenced Distance Vector (DSDV).

Reactive Schemes determine the route when needed. Therefore they have smaller Route Discovery overheads. They employ a flooding (global search) mechanism. A node trying to transmit a packet may have to wait for route discovery. Examples of such schemes are Dynamic Source Routing, Ad-Hoc On Demand Distance Vector Routing (AODV) etc.

Apart from proactive and reactive there is another mechanism called Flooding. In flooding no route is computed or discovered. A packet is broadcasted to all the nodes in the network. Flooding is the easiest routing method, however it generates heavy traffic. Different proactive, reactive and even hybrid (reactive as well as proactive) schemes e.g. Zone Routing Protocol, have been proposed for Wireless Ad-Hoc networks

2.2 Single path vs. multiple path

There are several criteria for comparing single-path routing and multi-path routing in ad hoc networks. First, the overhead of route discovery in multi-path routing is much more than that of single-path routing. On the other hand, the frequency of route discovery is much less in a network which uses multi-path routing, since the system can still operate even if one or a few of the multiple paths between a source and a destination fail. Second, it is commonly believed that using multipath routing results in a higher throughput. The reason is that all nodes are assumed to have (and limited) capacity (bandwidth and processing power). Since multi-path routing distributes the load better, the overall throughput would be higher.

2.3 Table driven vs. Source Initiated

In Table Driven Routing protocols, up-to-date routing information from each node to every other node in the network is maintained on each node of the network. The changes in network topology are then propagated in the entire network by means of updates. Destination Sequenced Distance Vector Routing (DSDV) and Wireless Routing Protocol (WRP) are two schemes classified under the table driven routing protocols head.

The routing protocols classified under Source Initiated On-Demand Routing, create routes only when desired by the source node. When a node requires a route to a certain destination, it initiates what is called as the route discovery process. This process basically comprises of packets with a description of the destination (address information of the destination etc.) being forwarded from one hop to the next. Any node receiving such a request looks into its available routing table to find if it has a route to the described destination. If a route to the destination is present, the node returns this route to the source and the process ends else the request packet is forwarded to its neighbors continuing the route search process. Once a route is found, it is temporarily maintained in some form (typically the routing table) and then subsequently removed after either a timeout, or if the destination node leaves the network etc. Some of the schemes classified under this head are Ad-Hoc On Demand Distance Vector Routing (AODV)[6], Dynamic Source Routing (DSR)[1,6], Temporally Ordered Routing Algorithm (TORA)[5] etc.

Position based routing algorithms claim that no routing tables need to be maintained and thus no overhead due to route discovery and route maintenance is imposed. But they need to obtain position data of their corresponding destinations, either by an internal discovery process, or by an independent position service, which will then impose overhead to maintain the position information (either proactively or on-demand). E.g. GPRS, LAR.

2.5 Source routing vs. hop by hop routing

A few routing protocols utilize source routing. This means, forwarding depends on the source of the message. Commonly, the source puts all the routing information into the header of a packet. Forwarding nodes utilize this information. In some cases, the forwarding nodes may alter the routing information in the packet to be forwarded. They are just a few protocols using source routing: CBRP, DSR [4]. In hop by hop routing, the route to a destination is distributed in the “next hop” of the nodes along the route. The problem is that all nodes need to maintain routing information and there may be a possibility of forming a routing loop.

2.6 Full/Limited/Local Broadcast

There is a full network broadcast, which means, a message is intended for every node in the network, and needs to be retransmitted by intermediate nodes. On the other hand, there is a local broadcast, which is intended for any node within the senders reach, but which is not retransmitted at all. In between there are limited broadcasts, in which the maximum hop count (time to live) is limited as desired. There is no routing protocol, that always issues full broadcasts, but there are some, that may use full broadcasts: ABR, ADV, CEDAR, DSDV [7], DSR, FORP and WAR. Many protocols prefer a limited broadcast: AODV [6], FSLS, FSR, HSR, LANMAR, LAR, LMR, SSR and ZRP. And also there are protocols, which use only local broadcasts: DDR, GSR, GPSR, OLSR, STAR, TBRPF, TORA [5] and WRP.

2.7 Recovery Mechanisms

Since the routing information in each node may become stale, some protocols may need a route recovery or route conservation mechanism. It is clear, that proactive routing protocols do not need a specific recovery mechanism, since they react to topology changes anyway within a short period. On-Demand protocols however, need to remove the routes which are not available any more. The following protocols have some (explicit or implicit) recovery mechanism: ABR, AODV [6], CBRP, DREAM3 DSR [1, 6], FORP, WAR and ZRP [8]. The following protocols could utilize such a mechanism, but do not support one: ADV, GEDIR, LAR.

2.8 Route Selection Strategy

The route selection strategy is an important aspect of a routing protocol. I describe the main representatives and the protocols, which use them. *Signal Strength*: Route packets along the connection with the best signal strength. This is mainly used by ABR and SSR. *Link Stability*: Route packets along the connections that appear most stable over a period of time. It is used by DST and FORP. *Shortest Path/Link State*: Select a shortest path according to some metric. This is used by many protocols: CEDAR, DDR, FSR, GSR, HSR, OLSR, STAR and TBRPF.

2.9 Periodic vs. Event Driven

Periodical update protocols disseminate routing information periodically. Periodical updates will simplify protocols and maintain network stability, and most importantly, enable (new) nodes to learn about the topology and the state of the network. However if the period between updates is large, the protocol may not keep the information up-to-date. On the other hand, if the period is small, too many routing packets will be disseminated which consumes the precious bandwidth of a wireless network. In an event-driven update protocol, when events occur, (such as when a link fails or a new link appears), an update packet will be broadcast and the up-to-date status can be disseminated over the network soon. The problem might be that if the topology of networks changes rapidly, a lot of update packets will be generated and disseminated over the network which will use a lot of precious bandwidth, and furthermore, may cause too much fluctuation of routes.

2.10 Flat vs. Hierarchical Structure

In a flat structure, all nodes in a network are at the same level and have the same routing functionality. Flat routing is simple and efficient for small networks. The problem is that when a network becomes large, the volume of routing information will be large and it will take a long time for routing information to arrive at remote nodes. For large networks, hierarchical (cluster-based) routing may be used to solve the above problems. In hierarchical routing the nodes in the network are dynamically organized into partitions called clusters, and then the clusters are aggregated again into larger partitions called superclusters and so on. Organizing a network into clusters helps maintain a relatively stable network topology. The high dynamics of membership and network topology is limited within clusters. Only stable and high level information such as the cluster level or the supercluster level will be propagated across a long distance, thus the control traffic (or routing overhead) may be largely reduced.

3. Qualitative Analysis

Qualitative analysis can be done on different criteria as follows

Protocol	Route Selection	Channel	Topology	Uni/non uni Protocol	Broadcast
LSR	Shortest Path	Single	Full	Uniform	Local
DVR	Link State	Single	Full	Uniform	Full
DSDV	Link State	Single	Full	Uniform	Full
GSR	Shortest Path	Single	Full	Uniform	Local
FSR	Shortest Path	Single	Reduced	Uniform	Limited
CSGR	Shortest Path	Multiple	Full	Non Uniform	Full
WRP	Shortest Path	Single	Reduced	Uniform	Local
DSR	Shortest Path	Single	Full	Uniform	Full
AODV	Shortest Path	Single	Full	Uniform	Full
TORA	Shortest Path	Single	Reduced	Uniform	Local
ABR	Signal Strength	Single	Full	Uniform	Full
HSR	Shortest Path	Single	Reduced	Non Uniform	Limited

Protocol	Routing Philosophy	Route Computation	Structure	Routes	Source Routing
LSR	Proactive	Decentralized	Flat	Single or Multiple	No may be Yes
DVR	Proactive	Distributed	Flat	Single	No
DSDV	Proactive	Distributed	Flat	Single	No
GSR	Proactive	Distributed	Flat	Single or Multiple	No may be Yes
FSR	Proactive	Distributed	Hierarchy	Single or Multiple	No may be Yes
CSGR	Proactive	Distributed	Flat	Single or Multiple	No may be Yes
WRP	Reactive	Distributed	Flat	Single	No
DSR	Reactive	Broadcast	Flat	Multiple	Yes
AODV	Reactive	Broadcast	Flat	Multiple	No
TORA	Reactive	Broadcast	Flat	Multiple	No
ABR	Reactive	Broadcast	Flat	Single	Yes
HSR	ProRea(Hybrid)	Heir Addr	Hierarchy	Single	No

Protocol	Update	Update information	Update Destination	Method
LSR	Hybrid	Neighbor's link State	All Nodes	Flooding
DVR	Periodical	Distance Vector	Neighbors	Broadcast
DSDV	Hybrid	Distance Vector	Neighbors	Broadcast
GSR	Periodical	Distance Vector	Neighbors	Broadcast
FSR	Periodical	Link State	Neighbors	Broadcast
CSGR	Periodical	Distance Vector	Neighbors and clus head	Broadcast
WRP	Hybrid	Distance Vector	Neighbors	Broadcast
DSR	Event-Driven	Route-error	Source	Unicast
AODV	Event-Driven	Route-error	Source	Unicast
TORA	Event-Driven	Node's Height	Neighbors	Broadcast
ABR	Event-Driven	Route-error	Neigh/Source	Bro/Uni
HSR	Per-Event	Virtual Link State	Nodes in cluster	Broadcast

3.2 Complexity of Routing Protocols

In this paper I define the storage, time and Communication complexity for different Routing protocols. Storage Complexity measures the order of the table size used by the protocols. Communication Complexity gives the no of messages needed to perform an operation when an update occurs.

Table 4 Complexity of Routing protocols			
Protocol	Time Complexity	Storage Complexity	Computational Complexity
LSR	$O(d)$	$O(N*A)$	$O(N)$
DVR	$O(d)$	$O(X)$	$O(N)$
DSDV	$O(d)$	$O(X)$	$O(N)$
GSR	$O(d)$	$O(N*A)$	$O(N)$
FSR	$O(d)$	$O(N)$	$O(N)$
CSGR	$O(d)$	$O(N/M)$	$O(N)$
WRP	$O(h)$	$O(X*A)$	$O(N)$
DSR	$O(2d)$	$O(E)$	$O(2N)$
AODV	$O(2d)$	$O(E)$	$O(2N)$
TORA	$O(2d)$	$O(Dd*A)$	$O(2N)$
ABR	$O(d)$	$O(D-A)$	$O(M*H)$
HSR	$O(D+r)$	$O(M*H)$	$O(N+Y)$

N=Number of nodes in the network
 E=Communication pairs
 M=Average no of nodes in a cluster
 H=No of Hierarchical Levels
 X=No of nodes affected by topological change
 d=Network diameter
 h=Height of routing tree
 r=diameter of desired paths where the reply packets transit
 Y=Total no of nodes forming the desired path where the reply packets pass
 A=average no of adjacent nodes
 Dd=No of maximum desired destinations

4. Quantitative Analysis

The main interest of the project was to test the ability of different routing protocols to react on network topology changes. Furthermore the focus was set on different network sizes, varying number of nodes and area sizes. I have taken 3 routing protocols in account, AODV, DSDV and ZRP. The main aim of taking these four protocols was that I wanted to include different kinds of protocols in this comparison, as I have on-demand vs. hybrid routing (ZRP), hop-by-hop vs. source routing. These three protocols cover almost all categories of protocols.

4.1 Simulation Environment

The simulations were performed using the QualNet Simulator v3.6 from Scalable Network Technologies, which is a commercial GloMoSim based product. The simulator is fully implemented in C++ while the graphical toolkit is implemented in Java. In this project, only the simulator part was used in order to speed up the simulations. The experiments were executed using the batch mode and the according configuration files.

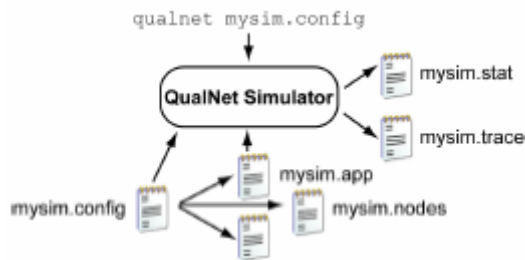


Figure 1

4.2 Metrics

The following four metrics have been chosen to compare the protocols:

4.2.1 Packet delivery ratio:

Packet delivery ratio is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source. It specifies the packet loss rate, which limits the maximum throughput of the network. The better the delivery ratio, the more complete and correct is the routing protocol.

4.2.2 Routing overhead:

The routing overhead describes how many routing packets for route discovery and route maintenance need to be sent in order to propagate the CBR packets. It is an important measure for the scalability of a protocol. It for instance determines, if a protocol will function in congested or low-bandwidth situations, or how much node battery power it consumes. If a protocol requires to send many routing packets, it will most likely cause congestion, collision and data delay in larger networks.

4.2.3 End-to-end delay

End-to-end delay indicates how long it took for a packet to travel from the CBR source to the application layer of the destination. It represents the average data delay an application or a user experiences when transmitting data.

4.2.4 Hop count

Hop count is the number of hops a packet took to reach its destination.

4.3 Simulation Results

We experimented with different network sizes from 50 up to 1000 nodes. The performance of AODV was very good in all network sizes. Almost all protocols perform relatively well in small networks (i.e. 50 nodes), when only few hops need to be taken to reach the destination node. Nevertheless, ZRP already at this point fails to deliver a greater percentage of the originated data packets - it only reaches a delivery ratio of 66%. As the network size grows, AODV always manages to deliver the packets with reliability greater than 90%. At a first glance, it can easily be stated that DSR and ZRP completely fail in larger networks: in a network of 200 nodes, the packet delivery drops below 30 percent

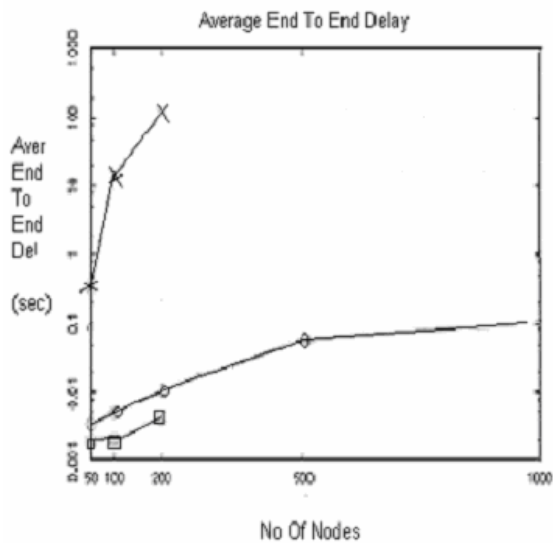


Figure 2(a)

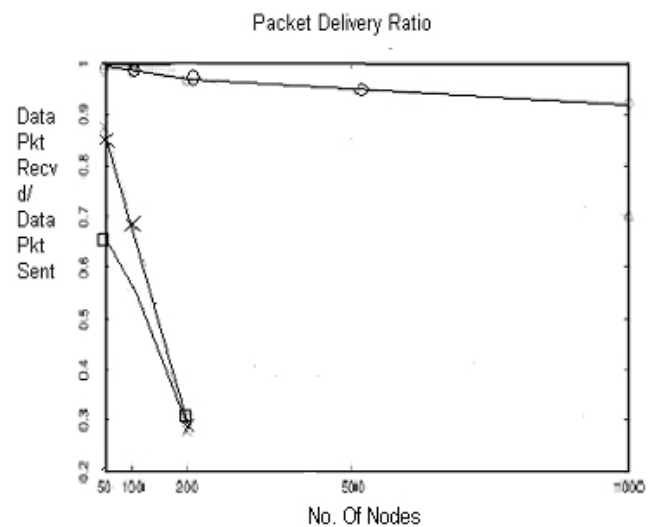


Figure 2(b)

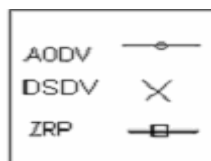


Figure 3

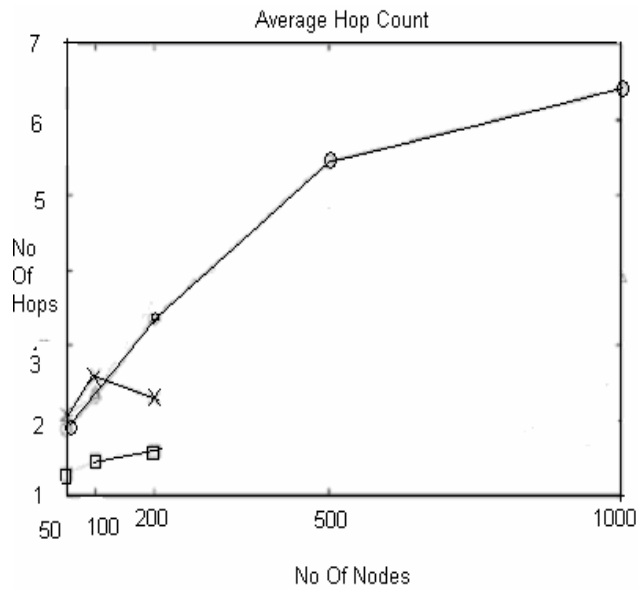


Figure 2(c)

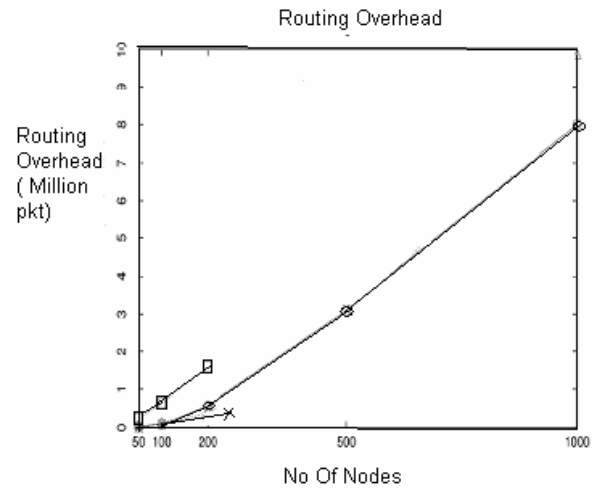


Figure 2d)

5. Conclusion:

In this paper I have discussed various criteria for classification of routing protocols and done both qualitative and quantitative analysis for wireless ad hoc networks. There are still many challenges facing wireless ad hoc networks. However because of their advantages, wireless ad hoc networks are becoming more and more prevalent in the world.

6. References

- [1] Josh Broch, David B. Johnson, and David A. Maltz. The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks. Internet-Draft, draft-ietf-manet-dsr-00.txt, March 1998. Work in progress.
- [2] M. Scott Corson and Anthony Ephremides. A distributed routing algorithm for mobile wireless networks. *Wireless Networks*, 1(1):61–81, February 1995.
- [3] David B. Johnson. Routing in ad hoc networks of mobile hosts. In *Proceedings of the IEEE Workshop on Mobile Computing Systems and Applications*, pages 158–163, December 1994.
- [4] David B. Johnson and David A. Maltz. Dynamic source routing in ad hoc wireless networks. In *Mobile Computing*, edited by Tomasz Imielinski and Hank Korth, chapter 5, pages 153–181, 1996.
- [5] Vincent D. Park and M. Scott Corson. Temporally-Ordered Routing Algorithm (TORA) version 1: Functional specification. Internet-Draft, draft-ietf-manet-tora-spec-00.txt, November 1997.
- [6] Charles Perkins. AdHoc On Demand Distance Vector (AODV) routing. Internet-Draft, draft-ietf-manet-aodv-00.txt, November 1997.
- [7] Charles E. Perkins and Pravin Bhagwat. Highly dynamic Destination- Sequenced Distance-Vector routing (DSDV) for mobile computers.
- [8] J. Schaumann, “Analysis of the zone routing protocol,” December 2002.