Effect of Quality Parameters on Energy Efficient Routing Protocols in MANETs

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***Abstract*—This paper presents a survey on energy efficient routing protocols for wireless Ad-Hoc networks. Survey focus on recent development and modifications in this widely used field. 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 NS2 to study their relative performance according to different criteria.**

Keywords- LSR: Link State Routing, DVR: Distance Vector Routing, DSDV: Destination Sequence Distance Vector Routing, FSR: Fisheye State Routing, CGSR: Clusterhead Gateway Switch Routing, WRP: Wireless Routing Protocol, DSR: Dynamic Source Routing, AODV: Ad Hoc On-Demand distance Vector Routing, TORA: Temporary Ordered Routing Algorithm, ABR: Associatively Based Routing Protocol, HSR: Hierarchical State Routing

I. INTRODUCTION

A mobile Ad hoc network (MANET) is an autonomous system of mobile hosts which are free to move around randomly and organize themselves arbitrarily. All wireless enabled devices within the range of each other can discover and communicate in a peer-to-peer fashion without involving central access points. In Ad hoc networks nodes can change position quite frequently. The nodes in an ad hoc network can be Laptops, PDA (personal digital Assistant) or palm tops etc. These are often limited in resources such as CPU capacity, storage capacity, Battery Power, Bandwidth. Each node participating in the network acts both as a router and as a host and must therefore is willing to transfer packets to other nodes. For this purpose a routing protocol should try to minimize control traffic. There is limitation of Battery life and in an Ad hoc environment battery is most commonly used.

MANETs have several salient characteristics:

1) Dynamic topologies
2) Bandwidth-constrained
3) Variable capacity links
4) Energy-constrained operation
5) Limited physical security [34]

II. CLASSIFICATION

Methods for classifying routing protocols for wireless ad hoc networks.
What routing information is exchanged?
When and how the routing information is exchanged.
When and how routes are computed and so on. We will discuss these criteria in this section.

A. 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. Packet forwarding is faster in these schemes as the route is already present [34].

a. Problems associated:-

1) Route discovery overheads are large in such schemes.
2) They consume bandwidth to keep routes up-to-date.

Examples: Destination Sequenced Distance Vector (DSDV), Fisheye state routing (FSR) [31].
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.

B. Single path vs. Multiple path

Single Path	**Multi Path**
1) Overhead of route discovery is less.	Overhead of route discovery is more.
2) Frequency of route discovery is more.	Frequency of route discovery is much less.
3) It results in lesser throughput.	It results in higher throughput.
4) It does not distribute the load evenly.	It distributes the load evenly.
5) It has less capacity.	It assumes to have more capacity.

C. 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. [34]
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)[13], Dynamic Source Routing (DSR)[1,15,31], Temporally Ordered Routing Algorithm (TORA)[1,31] etc.

D. 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 [31]. 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. [34]

E. 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[31], ADV, CEDAR[31], DSDV [19,31], DSR[1,31], FORP and WAR. Many protocols prefer a limited broadcast: AODV [15], FSLS, FSR[31], HSR[31], LANMAR, LAR, LMR, SSR[31] and ZRP[31]. And also there are protocols, which use only local broadcasts: DDR, GSR, GPSR, OLSR, STAR, TBRPF, TORA [31] and WRP.

F. Multicast vs Unicast routing

In multicast routing, data-packets are sent to only desire nodes of the network known as multicast group. Data packets are transferred between one to other group by transferring data packets between core/source of multicast group. It supports one-to-many approach for interaction. Example: Ad-Hoc Multicast Routing (AM Route)[31], On Demand Multicast Routing Protocol (ODMRP)[31].
Unicast routing allows data packets to transfer between two nodes. It supports one-to-one approach for interaction. All reactive and proactive routing protocols come under this category. [34]

G. Route Selection Parameter

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.

H. 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.[34]

I. 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. Examples: DSR (Dynamic Source Routing), AODV (Ad Hoc On-Demand distance vector routing), DSDV (destination sequence Distance Vector). [34]
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. The high dynamics of membership and network topology is limited within clusters. Only stable and high level information such as the cluster level will be propagated across a long distance, thus the control traffic (or routing overhead) may be largely reduced. Example: CGSR (Clusterhead Gateway Switch Routing)[31], HSR (Hierarchical State Routing)[31].

III. QUALITATIVE ANALYSIS

Qualitative analysis can be done on different criteria as follows [34]

TABLE I. COMPARISION OF ROUTING PROTOCOLS

Table 1 Comparison of routing protocols					
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

TABLE II. COMPARISION OF ROUTING PROTOCOLS

Table 2 Comparison of routing protocols					
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

TABLE III. COMPARISION OF ROUTING PROTOCOLS

Table 3 Comparison of routing protocols				
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

TABLE IV. COMPLEXITY OF ROUTING PROTOCOLS [34]

Table 4 : Comparison 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)

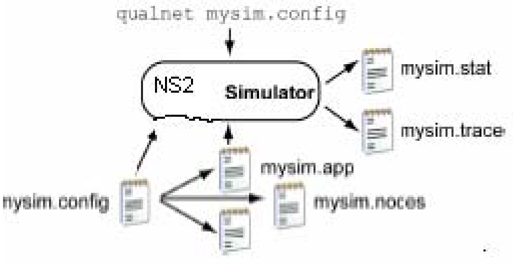
In this paper we define the storage, time and Communication complexity for different Routing protocols. Storage Complexity measures the order of the table size used by the protocols. Communication Complexity gives the no of messages needed to perform an operation when an update occurs.
N=Number of nodes 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 [34]

IV. 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 [15], DSDV [19,31] and ZRP[31]. 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.

A. Simulation Environment

The simulations were performed using the NS2 simulator version ns2.34. The simulator is fully implemented in TCL and OTCL while the graphical toolkit is implemented in NAM and the graphs are implemented in .net technology. 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. [34]



B. Metrics

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

a. 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.

b. 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 sending many routing packets, it will most likely cause congestion, collision and data delay in larger networks.

c. 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.

d. Hop count

Hop count is the number of hops a packet took to reach its destination[34]

C. 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. [34]

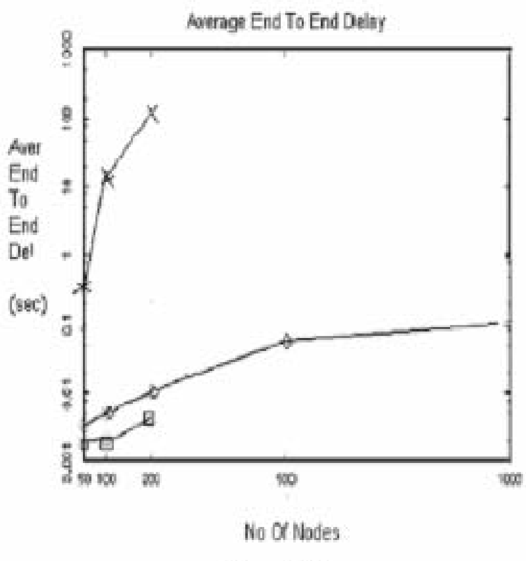


Figure 2(a)

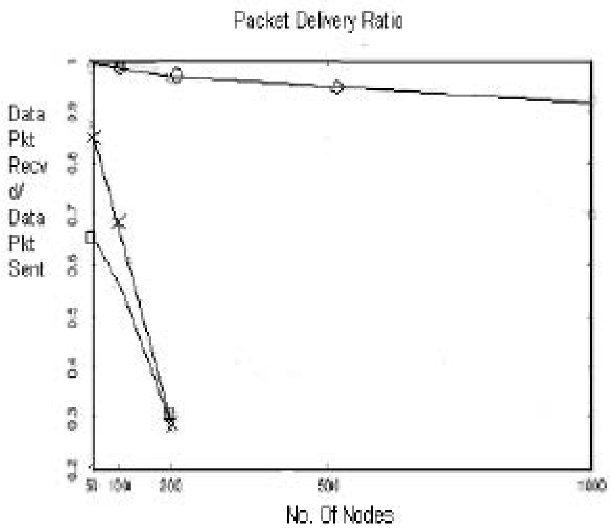


Figure 2(b)

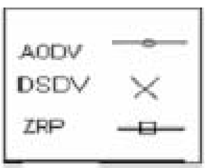


Figure 3

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