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Comparative Analysis of Energy Efficient Routing Protocols in MANETS (Mobile Ad-hoc Networks)

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Abstract
Mobile ad hoc networks (MANET) represent distributed systems that consist of wireless mobile nodes that can freely and dynamically organize itself into temporary ad hoc network topologies. A mobile ad hoc network is a collection of nodes that is connected through a wireless medium forming rapidly changing topologies. Manets are infrastructure less and can be set up anytime, anywhere. We have conducted survey of simulation results of various Manet routing algorithms and analyzed them. The routing algorithms considered are classified into two categories proactive and reactive. The algorithms considered are AODV, DSR, and DSDV. The performance measurements are based on the various parameters such as packet delivery fraction, average end to end delay and number of packets dropped. Future work in this area includes development of efficient routing protocols so as to improve the performance of the parameter in which the particular routing protocol is lagging.

Keywords
Mobile Ad hoc Network, Simulation, AODV, DSR, DSDV, Packet Delivery Fraction, Average End to End Delay, Number of Packets Dropped.

I. Introduction

Communication has become very important for people to exchange information anytime from and to anywhere. With the widespread rapid development of computers and the wireless communication, the mobile computing has already become the field of computer communications in high-profile link. Mobile Ad-hoc Network usually has a dynamic shape and a limited bandwidth. Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature; the use of mobile networks is growing very fast. In particular, a very large number of recent studies focused on Mobile Ad-hoc Networks (MANETs) [3,7]. The performance of a mobile ad-hoc network depends on the routing scheme employed, and the traditional routing protocols do not work efficiently in a MANET. Developing routing protocols for MANETs has been an extensive research area in recent years, and many proactive, reactive and hybrid protocols have been proposed from a variety of perspectives [7]. These protocols try to satisfy various properties, like: distributed implementation, efficient utilization of bandwidth and battery capacity, optimization of metrics, fast route convergence and freedom from loops. Wireless mobile ad-hoc networks are useful in many areas which are as follows:

A. Military environments

- Automated battlefield
- Special operations
- Homeland defense
- Soldiers, tanks, plants

B. Civilian environments

- Disaster Recovery (flood, fire, earthquakes etc)
- Law enforcement (crowd control)
- Search and rescue in remote areas
- Environment monitoring (sensors)
- Space/planet exploration
- Boats, small aircraft
- Sports stadiums
- Taxi cab network

C. Commercial

- Sport events, festivals, conventions
- Patient monitoring
- Ad hoc collaborative computing (Bluetooth)
- Sensors on cars (car navigation safety)
- Vehicle to vehicle communications
- Video games at amusement parks, etc

II. Mobile Ad Hoc Network Routing Protocols

A. Protocol Classifications

There are many ways to classify the MANET routing protocols (Fig.1), depending on how the protocols handle the packet to deliver from source to destination. But Routing protocols are broadly classified into three types such as Proactive, Reactive and Hybrid protocols [2].

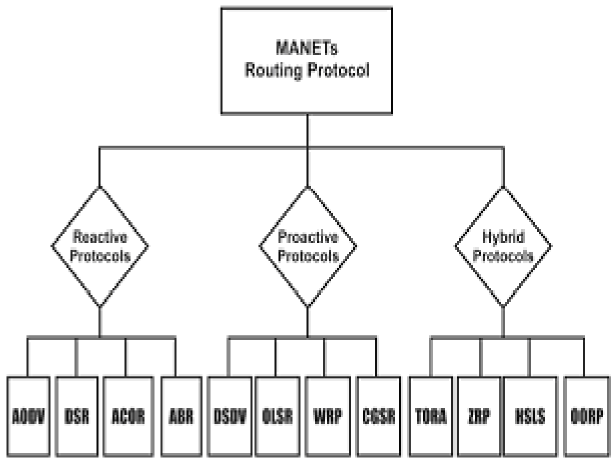

Fig.1: MANET Routing Protocols

1. Proactive Protocols:

These types of protocols are called table driven protocols in which, the route to all the nodes is maintained in routing table. Packets are transferred over the predefined route specified in the routing table. In this scheme, the packet forwarding is done faster but the routing overhead is greater because all the routes have to be defined before transferring the packets. Proactive protocols have lower latency because all the routes are maintained at all the times.
Example protocols: DSDV, OLSR (Optimized Link State Routing)

2. Reactive Protocols

These types of protocols are also called as On Demand Routing Protocols where the routes are not predefined for routing. A Source node calls for the route discovery phase to determine a new route whenever a transmission is needed. This route discovery

mechanism is based on flooding algorithm which employs on the technique that a node just broadcasts the packet to all of its neighbors and intermediate nodes just forward that packet to their neighbors. This is a repetitive technique until it reaches the destination. Reactive techniques have smaller routing overheads but higher latency.
Example Protocols: DSR, AODV

3. Hybrid Protocols

Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols and as a result, routes are found quickly in the routing zone.
Example Protocol: ZRP (Zone Routing Protocol)

B. Overview of Routing Protocols

In this section, a brief overview of the routing operations performed by the familiar protocols. DSDV, AODV and DSR are discussed.

1. Destination-Sequenced Distance-Vector (DSDV) protocol:

The Table-driven DSDV protocol is a modified version of the Distributed Bellman-Ford (DBF) Algorithm that was used successfully in many dynamic packet switched networks [12]. The Bellman-Ford method provided a means of calculating the shortest paths from source to destination nodes, if the metrics (distance-vectors) to each link are known. DSDV uses this idea, but overcomes DBF's tendency to create routing loops by including a parameter called destination-sequence number.

In DSDV, each node is required to transmit a sequence number, which is periodically increased by two and transmitted along with any other routing update messages to all neighboring nodes. On reception of these update messages, the neighboring nodes use the following algorithm to decide whether to ignore the update or to make the necessary changes to its routing table:

Step 1: Receive the update message
Step 2: Update the routing table if any one of the following condition satisfies:
i) Sn > Sp
ii) Sn=Sp, Hop count is less
Otherwise, ignore the update message.
Here, Sn and Sp are the Sequence numbers of new message and existing message respectively. When a path becomes invalid, due to movement of nodes, the node that detected the broken link is required to inform the source, which simply erases the old path and searches for a new one for sending data. The advantages are latency for route discovery is low and loop-free path is guaranteed. The disadvantage is the huge volume of control messages.

2. Ad Hoc On-demand Distance Vector Routing (AODV) protocol:

The Ad Hoc On-demand Distance Vector Routing (AODV) protocol is a reactive unicast routing protocol for mobile ad hoc networks [10]. As a reactive routing protocol, AODV only needs to maintain the routing information about the active paths. In AODV, the routing information is maintained in the routing tables at all the nodes. Every mobile node keeps a nexthop routing table, which contains the destinations to which it currently has a route. A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time.

In AODV, when a source node wants to send packets to the destination but no route is available, it initiates a route discovery operation. In the route discovery operation, the source node broadcasts route request (RREQ) packets which includes Destination Sequence Number. When the destination or a node that has a route to the destination receives the RREQ, it checks the destination sequence numbers it currently knows and the one specified in the RREQ. To guarantee the freshness of the routing information, a route reply (RREP) packet is created and forwarded back to the source only if the destination sequence number is equal to or greater than the one specified in RREQ. AODV uses only symmetric links and a RREP follows the reverse path of the respective RREQ. Upon receiving the RREP packet, each intermediate node along the route updates its next-hop table entries with respect to the destination node. The redundant RREP packets or RREP packets with lower destination sequence number will be dropped. The advantage of this protocol is low Connection setup delay and the disadvantage is more number of control overheads due to many route reply messages for single route request.

3. Dynamic Source Routing (DSR) Protocol:

The Dynamic Source Routing (DSR) is a reactive unicast routing protocol that utilizes source routing algorithm [11]. In DSR, each node uses cache technology to maintain route information of all the nodes. There are two major phases in DSR such as:

- Route discovery
- Route maintenance

When a source node wants to send a packet, it first consults its route cache [7]. If the required route is available, the source node sends the packet along the path. Otherwise, the source node initiates a route discovery process by broadcasting route request packets. Receiving a route request packet, a node checks its route cache. If the node doesn't have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node's route cache. Whenever the data link layer detects a link disconnection, a OUTE_ERROR packet is sent backward to the source in order to maintain the route information. After receiving the ROUTE_ERROR packet, the source node initiates another route discovery operation.

Additionally, all routes containing the broken link should be removed from the route caches of the immediate nodes when the ROUTE_ERROR packet is transmitted to the source. The advantage of this protocol is reduction of route discovery control overheads with the use of route cache and the disadvantage is the increasing size of packet header with route length due to source routing.

4. Associativity Based Routing (ABR) Protocol :

It is a source-initiated routing protocol, which means that there is no need for periodic route updates. ABR selects route based on the temporal stability of the links between the nodes. ABR is beacon-based, so that each node generates periodic beacons (hello messages) to signify its existence to the neighbors. These beacons are used

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to update the associativity table of each node. With the temporal stability and the associativity table the nodes are able to classify each neighbor link as stable or unstable. ABR takes up a few metrics like. The fundamental objective of ABR is to find longer-lived routes. ABR consists of 3 phases:

1. Route Discovery
2. Route Repair/Reconstruction
3. Route Delete

5. Location-Aided Routing Protocol :

LAR is an on-demand protocol who is based on the DSR (Dynamic Source Routing).The Location - Aided Routing Protocol uses location information to reduce routing overhead of the ad-hoc network! Normally the LAR protocol uses the GPS (Global Positioning System) to get these location informations. With the availability of GPS, the mobile hosts knows there physical location.

To reduce the complexity of the protocol, we assume, that every host knows his position exactly, the difference between the exact position and the calculated position of GPS will no be considered! We also assume that the mobile nodes are only moving in a two-dimensional plane.

6. Temporally-Ordered Routing Algorithm (TORA) :

TORA also maintains a DAG by means of an ordered quintuple with the following information:

- t time of a link failure
- oid originator id
- r reflection bit indicates 0=original level 1=reflected level
- d integer to order nodes relative to reference level
- i the nodes id

The triplet (t,oid,r) is called the reference level. And the tuple (d,i) is said to be an offset within that reference level. The heights of the nodes for a given destination to each other determine the direction of the edges of the directed acyclic graph. The DAG is destination oriented (routed at the destination) when the quintuples which represent the heights are maintained in lexicographical order, the destination having the smallest height, traffic always flowing downstreams. Heights are however not needed for route discovery, instead a mechanism as in LMR is used. Also nodes which do not currently need to maintain a route for themselves or for others won’t change a height value. Each node has a Route-required flag for that purpose , additionally the time since the last UPD (update) packet was sent is recorded. Each node maintains a neigbour table containing the height of the neighbour nodes. Initially the height of all the nodes is NULL. (This is not zero “0” but NULL “-”) so their quintuple is (-,-,-,-,i). The height of a destination neighbour is (0,0,0,0,dest).

g. Zone Routing Protocol (ZRP): The Zone Routing Protocol (ZRP) is either a proactive or reactive protocol. It is a hybrid routing protocol. It combines the advantages from proactive (for example AODV) and reactive routing (OLSR). It takes the advantage of pro-active discovery within a node’s local neighbourhood (Intrazone Routing Protocol (IARP)), and using a reactive protocol for communication between these neighbourhoods (Interzone Routing Protocol (IERP)). The Broadcast Resolution Protocol (BRP) is responsible for the forwarding of a route request. ZRP divides its network in different zones. That’s the nodes local neighbourhood. Each node may be within multiple overlapping zones, and each zone may be of a different size. The size of a zone is not determined by geographical measurement. It is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone.

Table 1: Comparison of different routing protocols [13]

Protocol	Route	Route Selection Criteria	Beacon	Maintenance	Route discovery
DSR	Multiple	Shortest path	No	Global, notify source	Global
ABR	Single	Link Stability	Yes	Local, bypass broken link	Global
SSA	Single	Signal Strength	Yes	Global, notify source	Global
AODV	Single	Shortest path	Yes	Global, notify source	Global
LAR	Multiple	Shortest path	No	Global, notify source	Localized

III. Challenges in Mobile Ad-hoc networks

Ad-hoc networks have to suffer many challenges at the time of routing. Dynamically changing topology and no centralized infrastructure are the biggest challenges in the designing of an Ad-hoc network. The position of the nodes in an Ad-hoc network continuously varies due to which we can’t say that any particular protocol will give the best performance in each and every case topology varies very frequently so we have to select a protocol which dynamically adapts the ever-changing topology very easily. Another challenge in MANET is limited bandwidth. If we compare it to the wired network then wireless network has less and more varying bandwidth, so bandwidth efficiency is also a major concern in Ad-hoc network routing protocols. Limited power supply is the biggest challenge of an Ad-hoc network so if we want to increase the network lifetime (time duration when the first node of the network runs out of energy) as well the node lifetime then we must have an efficient energy management protocol. So an Ad-hoc routing protocol must meet all these challenges to give the average performance in every case.

Current research challenges in ad-hoc networks are as follow:

- Energy Saving
- Limited wireless transmission range
- Broadcast nature of the wireless medium
- Packet losses due to transmission errors
- Mobility-induced route changes
- Mobility-induced packet losses
- Battery constraints
- Potentially frequent network partitions
- Ease of snooping on wireless transmissions (security hazard)
- Limited Power Supply

IV. Energy Efficiency

For a wireless networks, the devices operating on battery try to pursue the energy efficiency heuristically by reducing the energy they consumed, while maintaining acceptable performance of certain tasks. Using the power consumption is not only a single criterion for deciding energy efficiency. Actually, energy efficiency can be measured by the duration of the time over which the network can maintain a certain performance level, which is usually called as the network lifetime. Hence routing to maximize the lifetime of the network is different from minimum energy routing. Minimum energy routes [1,6] sometimes attract more flows, and the nodes in these routes exhaust their energy very soon; hence the whole network cannot perform any task due to the failure on these nodes. In other words, the energy consumed is balanced consumed among nodes in the networks. Routing with maximum lifetime balances all the routes and nodes globally so that the network maintains certain performance level for a longer time. Hence, energy efficiency is not only measured by the power consumption but in more general it can be measured by the duration of time over which the network can maintain a certain performance level. It goes without saying that node failure is very possible in the wireless network.Hence saving energy when broadcasting in order to recover from the node failure or to re-routing around the failed nodes is essential. By the same token, multicast has the same challenge to achieve the energy efficiency [8, 9]. For unicast, it is highly related to the node and link status, which require a wise way to do routing as well. Sometimes, shortest path routing is possibly not the best choice from the energy efficiency point of view.

V. Comparison of Routing Protocols

A. Number of Packets Dropped

The number of data packets that are not successfully sent to the destination. In terms of dropped packets, AODV's performance is the worst (Fig. 2). The performance degrades with the increase in the number of nodes. As the number of nodes increases the number of packets dropped increases which means that number of packets not successfully reaching the destination has also increased. DSDV performs consistently well with increase in the number of nodes. The number of packets dropped is negligible which means that almost all packets reach the destination successfully. DSR performs
fine when number of nodes is less but fails slightly to perform with increase in the number of nodes. The packets dropped are much less compared to performance of AODV (Fig. 2).

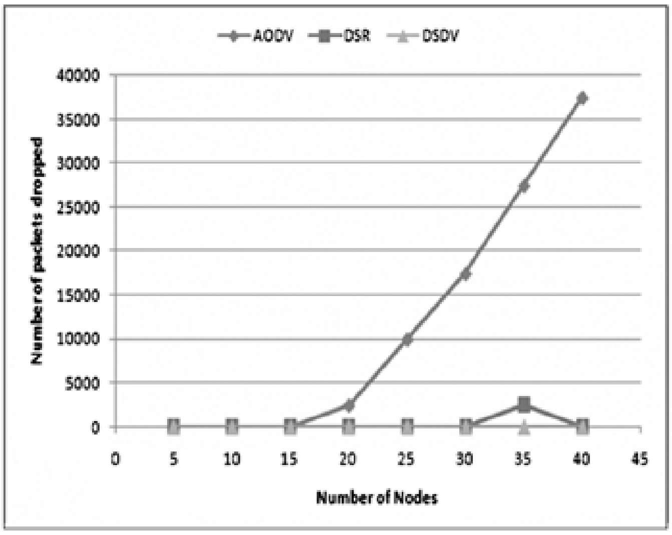

Fig. 2: Dropped Packets for AODV, DSR, DSDV [14].

B. Average End to End Delay Result

When buffers become full, the packets have to stay in the buffers a much longer period of time before they are sent. This can be seen at the DSR routing protocol when it was reach around 2300 packets at the 0 mobility (Fig. 3). For average end-to-end delay, the performance of DSR decreases and varies with the number of nodes. However, the performance of DSDV is degrading due to increase in the number of nodes the load of exchange of routing tables becomes high and the frequency of exchange also increases due to the mobility of nodes. The performance of AODV decreases and remains constant as the number of nodes increases (Fig.4).

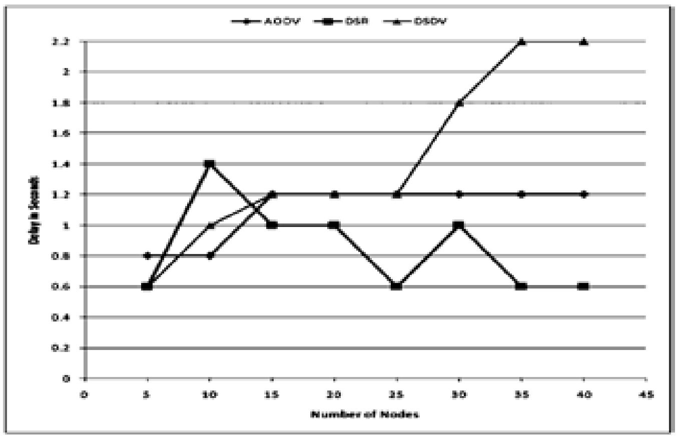

Fig. 3: Average End to End Delay for AODV, DSR, DSDV [14]

3. Packet Delivery Ratio

Packet Delivery Ratio is the ratio between the numbers of packets originated by the application layer sources and the number of packets received by the sinks at the final destination. It will describe the loss rate that will be seen by the transport protocols, which in turn affects the maximum throughput that the network can support. In terms of packet delivery ratio, DSR performs well when the number of nodes is less as the load will be less (Fig. 4). However its performance declines with increased number of nodes due to more traffic in the network. The performance of DSDV is better with more number of nodes than in comparison with the other two protocols. The performance of AODV is better at the beginning and decreases slightly with increase in number of nodes (Fig 4).

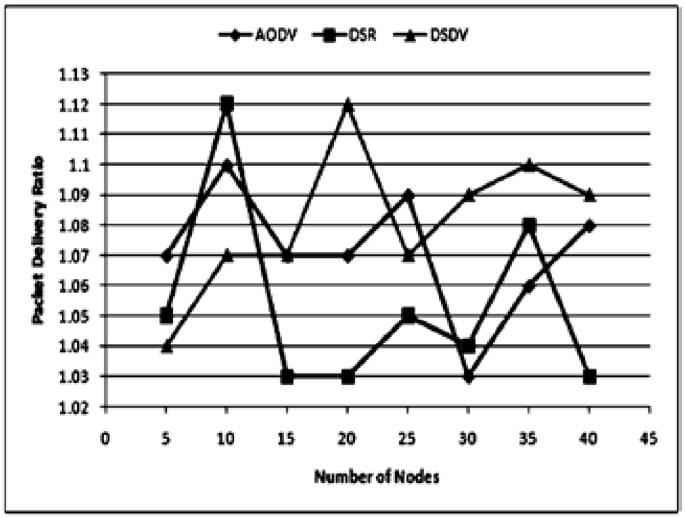

Fig. 4: Packet Delivery Ratio for AODV, DSR, DSDV[14].

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