Energy Efficient Routing Protocols in Mobile Ad Hoc Network (MANET) – A Review

S.Divya[1], B.Murugesakumar[2]

[1]Research Scholar, Department of Computer Science,
Dr. SNS Rajalakshmi College of Arts & Science, Coimbatore
divyasubramaniyam@gmail.com

[2]Head, Department of Computer Applications,
Dr. SNS Rajalakshmi College of Arts & Science, Coimbatore
gbmurugesh@gmail.com

Abstract: ***Mobile ad hoc networks (MANET) represent distributed systems that consist of wireless mobile nodes that can freely organize it into temporary ad hoc network topologies. A mobile ad hoc network is a collection of nodes that is connected through a wireless medium forming dynamic topologies. If a node is used frequently for transmission or overhearing of data packets, more energy is consumed by that node and after certain amount of time the energy level may not be sufficient for data transmission resulting in link failure. MANET's are generally battery-powered devices, the critical aspect is to reduce the energy consumption of nodes, so that the network lifetime can be extended. Since the network interface is a significant consumer of power, considerable research has been done to low-power design of the entire network protocol stack of wireless networks in an effort to enhance energy efficiency. This paper presents a review on the energy efficient routing protocols in Mobile Ad-Hoc Network (MANET).***

Keywords: Energy-efficient, MANET, Routing Protocols

1. Introduction

Mobile ad hoc network (MANET) is composed of a collection of mobile nodes which can move freely. Therefore, dynamic topology, unstable links, limited energy capacity and absence of fixed infrastructure are special features for MANET when [15] compared to wired networks. MANET does not have centralized controllers, which makes it different from traditional wireless networks (cellular networks and wireless LAN). Due to these special features, the design of routing protocols for MANET becomes a challenge. Routing is one of the key issues in [2] MANETs due to their highly dynamic and distributed nature. In particular, energy efficient routing may be the most important design criteria for MANETs since mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. The lifetime of the network in the scientific papers reviewed is usually defined according to the following criteria: 1) the time period until the first node burns out its entire battery budget, 2) the time until certain percentage of the nodes fail, 3) the time until network partitioning.

Some challenges that ad-hoc networking faces are limited wireless transmission range, hidden terminal problems, packet losses due to transmission errors, mobility induced route changes, and battery constraints. Mobile ad-hoc networks could enhance the service area of access networks and provide wireless connectivity into areas with poor or previously no coverage Connectivity to wired infrastructure will be provided through multiple gateways with possibly different capabilities and utilization. Ad-hoc networking brings features like easy connection to access networks, dynamic multi hop network structures, and direct peer-to-peer communication. The multi hop property of an ad-hoc network needs to be bridged by a gateway to the wired backbone.

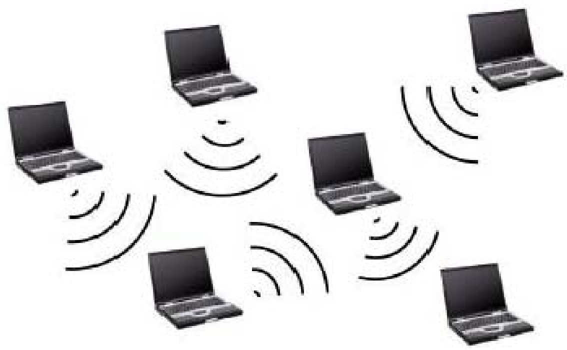

Figure 1: A Mobile ad hoc Network

Figure 1 shows a simple mobile ad hoc network. MANET is decentralized and self-organizing network where the functions from discovering the network topology to delivering the message are carried out by the nodes themselves;[10] In this network each node acts as a router along with its job as an ordinary device. The organization of Ad hoc networks is peer-to-peer multi hop and information packets are relayed in a store-and-forward mode from a source to any arbitrary destination via intermediate nodes. As the nodes are mobile, any change in network topology must be communicated to other nodes so that the topology information can be updated or eliminated. It is not possible for all mobile nodes to be within the range of each other. However, all the nodes are close by within radio range.

1.1 Characteristics of a MANET

MANET is characterized by some specific features as follows:

- **Wireless:** The nodes are connected by wireless links and the communication among nodes is wirelessly [3].
- **Ad hoc based:** A MANET is a need based network formed by the union of nodes and the connecting links in an arbitrary fashion. The network is temporary and dynamic.
- **Dynamic Topologies:** Due to arbitrary movement of nodes at varying speed, the topology of network may change unpredictably and randomly.
- **Multi hop Routing:** There is no dedicated router and every node acts as a router to pass packets to other nodes.
- **Autonomous and infrastructure less:** Network is self-organizing and is independent of any fixed infrastructure or centralized control. The operation mode of each node is distributed peer-to-peer capable of acting as an independent router as well as generating independent data.
- **Energy Constraint:** Energy conservation becomes the major design issue as nodes in the MANET rely on batteries or some other exhaustible source of energy.

1.2 Applications of MANET

Wireless mobile ad-hoc networks are useful in many areas which are as follows:[15]

1. Military environments

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

2. 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

3. 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

2. Energy Efficient Routing

In 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 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 re-routing around the failed nodes is essential. By the same token, multicast has the same challenge to achieve the energy efficiency. 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. An ideal network is the one that can function as long as possible. On the other hand, optimal routing requires future knowledge and thus, it is not practically viable to have optimized routing in energy constrained environment. Therefore, instead of having energy optimal scheme, we have a statistically optimal **energy efficient** scheme that considers only past and present and not future knowledge.[10] In order to avoid coverage gap in many surveillance / monitoring applications, **lifetime** of network is defined. Instead of average time or overall scenarios, the worst case (when a first node dies out) is maximized. Establishing correct and energy efficient routes, in mobile ad hoc networks, is not only an important design issue but also a challenging task. It is because operation time of mobile nodes is the most critical limiting factor. Mobile nodes derive their power from batteries with limited capacity. Power failure of a mobile node affects the node as well as its ability to propagate packets on behalf of others and therefore the overall network lifetime is affected. Energy efficient routing aims to minimize the energy required to transmit or receive packets i.e., active communication energy. It also tries to minimize the energy consumed when a mobile node stays idle but listens to the wireless medium for any possible communication requests from other nodes i.e., inactive energy. Transmission power control approach and load distribution approach minimizes active communication energy and sleep/power-down mode approach minimizes inactive energy.

3. Energy Efficient Ad Hoc Routing Protocols

A routing protocol is the software or hardware implementation of a routing algorithm. A routing protocol uses metrics to select a path to transmit a packet across an internetwork. The metrics used by routing protocols include:

- Number of network layer devices along the path (hop count)
- Bandwidth , Delay & Load

- Maximum Transmission Unit (MTU)
- Cost (in terms of Energy Consumption and Time)

Routing is one of the major challenges in MANETs due to their highly dynamic and distributed nature. MANET routing protocols depending on how the protocols handle the packet to deliver from source to destination. The routing protocols can be classified into two parts: 1. Proactive (Table driven) and 2. Reactive (Source initiated) routing protocols. Depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing. The combination of Reactive (On demand) and Proactive (Table driven) protocols is called Hybrid Routing Protocols.

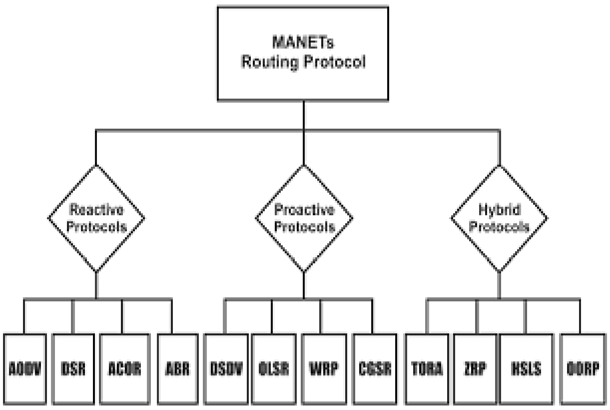

Figure 2: Categorization of ad-hoc routing protocol

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. [3] The routing table contains a list of all the destinations, the next hop, and the number of hops to each destination. Each node updates its routing table in response to the change in network and communicates the updates to all its neighboring nodes. The table is created using either link-state or distance vector algorithmic approach. 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: DSR (Dynamic Source Routing), AODV (Ad Hoc On Demand Distance Vector Routing), ABR (Associativity Based Routing), ACOR (Admission Control enabled On-demand Routing).

2. Reactive Protocols

These types of protocols are also called as On Demand Routing Protocols where the routes are not predefined for routing. *Route discovery* and *route maintenance* are two main procedures: The route discovery process involves sending route-request packets from a source to its neighbor nodes, which then forward the request to their neighbors, and so on. Once the route-request reaches the destination node, it responds by neighbor from which an intermediate node that has a sufficiently unicasting a route-reply packet back to the source node via the up-to-date route, it stops forwarding and sends a route-reply message back to the source. it first received the route-request. When the route-request reaches Once the route is established, some form of route maintenance process maintains it in each node's internal data structure called a route-cache until the destination becomes inaccessible along the route.[3] Note that each node learns the routing paths as time passes not only as a source or an intermediate node but also as an overhearing neighbor node. In contrast to table-driven routing protocols, not all up-to-date routes are maintained at every node. Reactive techniques have smaller routing overheads but higher latency.

Example Protocols: DSDV (Destination –Sequenced Distance Vector routing), OLSR (Optimized Link State Routing), Wireless Routing Protocol (WRP), Cluster head Gateway Switch Routing (CGSR).

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 [3]. The route established with proactive routes and uses reactive flooding for new mobile nodes.

Example Protocols: ZRP (Zone Routing Protocol), Temporally Ordered Routing Algorithm (TORA), Orderone Routing protocol (OOPR), Hazy sighted Link state (HSLS). [11] The below Table1: shows the comparison of the characteristics of the routing protocols.

Table1: Comparison of Routing

Characteristics	Proactive	Reactive	Hybrid
Network Organization	Flat Hierarchal	Flat	Hierarchal
Topology Dissemination	Periodical	On-Demand	Both
Route Latency	Always Available	Available When Needed	Both
Mobility Handling	Periodical Updates	Route Maintenance	Both
Communication Overhead	High	Low	Medium

3.1 Overview Of Routing Protocols

In this section, the overview of routing operations performed by the routing protocols like AODV, DSR, ABR, DSDV, TORA, CGSR are discussed.

1. **Ad Hoc On-demand Distance Vector Routing (AODV) Protocol:**

The Ad Hoc On-demand Distance Vector Routing (AODV) [3] protocol is a reactive unicast routing protocol for mobile ad hoc networks. As a reactive routing protocol, AODV only needs to maintain the routing information about the active paths. Builds an DSDV algorithm and the improvement is on minimising the number of required broadcasts by creating routers on an on-demand basis.[15] In AODV, the routing information is maintained in the routing tables at all the nodes. Every mobile node keeps a next hop 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.[4] 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.

Advantage:

- Low Connection setup delay
- Uses Bandwidth efficiently

Disadvantage:

- More number of control overheads due to many routes replies messages for single route request.
- Node uses the routing cache to reply to route queries.

2. Associativity Based Routing (ABR) Protocol:

Associativity Based Routing is free from loops, deadlock and packet duplicates and defines a new routing metric for ad hoc networks. Each node generates periodic beacons (Hello messages) to signify its existence to the neighbours. These beacons are used to update the associativity table of each node with the temporary stability and the associativity table the nodes are able to classify each neighbour link as stable or unstable.

ABR consists of 3 phases:

- Route Discovery
- Route Repair/Reconstruction
- Route Delete

3. Dynamic Source Routing (DSR) Protocol:

In DSR, the routing is based on the concept of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware.
DSR consists of 2 major phases:

- Route Discovery - Uses Route Request and Route Reply packets.
- Route Maintenance - Uses Route error packets and acknowledgements.

Advantages:

- No periodic hello messages and fast recovery cache can store multiple paths to a destination.

Disadvantages:

- The packets may be forwarded along cached routers.
- Scalability problem occurs due to the nature of source routing. Same as AODV, nodes use the routing caches to reply the route queries.

4. Destination-Sequenced Distance-Vector Routing (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 [3].

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 neighbouring nodes. On reception of these update messages; the neighbouring 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.

Advantages

- Latency for route discovery is low
- Loop free path is guaranteed.

Disadvantage

- Huge volume of control messages.

5. Cluster head Gateway Switch Routing (CGSR) Protocol:

It uses DSDV as an underlying protocol and least cluster change (LCC) clustering algorithm. A cluster head is able to control a group of ad hoc hosts. Each node maintains two tables

- A cluster member table, containing the cluster head for each destination node.
- A Distance Vector routing table, containing the next hop to the destination.

The routing principle is to lookup of the cluster head of the destination node, Lookup of the next hop, packet send to destination, Destination cluster head delivers packet.

Drawbacks:

- Too frequent cluster head selection can be an overhead and cluster nodes and gateway can be a bottle neck.

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 [3] (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 down streams. 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 [12] 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 neighbour 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). e.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 (Intra zone Routing Protocol (IARP)), and using a reactive protocol for communication between these neighbourhoods (Inter zone 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.

Advantages:

- Provides loop free paths at all instants and multiple routes so that if one path is not available, other is readily available.
- It establishes routes quickly so that they may be used before the topology changes.

Disadvantages:

- While MANETs are self -contained they can also be tied to an Ip-based global or local network i.e. Hybrid network.

4. Conclusion

In this paper, discussion is done on the energy efficient routing protocols in mobile ad hoc networks and an overview of some of the routing protocols like DSDV, DSR, ABR, AODV, TORA, CGSR. A brief idea is given for the function of energy efficient routing protocols.

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Author Profile

S.Divya received the Bachelor degree in Computer Science and Master Degree in Computer Technology from Kongunadu Arts & Science College, Coimbatore in 2009 and 2011, respectively. Currently pursuing Master of Philosophy in Computer Science in Dr. SNS Rajalakshmi College of Arts & Science, Coimbatore under the Guidance of Mr. B. Murugesakumar M.C.A., M.Phil, Head, Department of Computer Applications. Her area of Interest is Mobile Ad Hoc Networks.