A study of recent researches in Energy Efficient routing protocols for battery constrained Mobile ad hoc networks

P. Manickam ¹, Dr. D. Manimegalai ²

¹ Department of Applied Sciences, Sethu Institute of Technology, India
² Department of Information Technology, National Engineering College, India
E-mail: ¹softpm@gmail.com, ²gm7576@gmail.com

Abstract: Mobile Ad hoc NETwork (MANET) is a collection of wireless mobile nodes that communicate with each other in the absence of fixed infrastructure. Due to the absence of fixed infrastructure, each node communicates with another in multi hop manner. In MANET, mobile nodes are operating in battery energy, energy becomes a scare resource. Nodes are also joining and leaving the network at unpredicted time. Designing energy efficient routing protocol is a challenging task for mobile ad hoc networks. Before developing any routing protocol, the existing routing protocols should be studied. This paper highlights the classification of routing protocols and recently developed energy saving algorithms and protocols.

Keywords:- Node Energy, Hello packet, Power management.

I. INTRODUCTION

Nowadays, wireless system application like mobile phone has become an essential part of communication. Due to numerous characteristics and applications wireless systems, it is a predominant technology to all domains. Ad hoc networks are categorized into the three generations of systems. In 1972, the first generation introduced the Packet Radio Networks. In 1980, the second generation of ad-hoc networks came out as a part of the Survivable Adaptive Radio Networks program. Third generation ad-hoc networks systems emerge new system as we are using current ad hoc networks. Current ad hoc networks emerges many significant features within the radios’ performance by making them user friendly and customized to simple economical and performing the operations against various attacks. Due to continuous and progressive research in this domain, ad-hoc networks arrive with notebook computers and other feasible communication devices. Research community has collaborated ad hoc networks with mobile devices to provide the services to the society.

Mobile Ad hoc NETwork (MANET) is a collection of auto-configuring wireless easily deployable mobile nodes [1]. In MANET, network topology will change unpredictably due to nodes changing their position very often. Due to the absence of fixed infrastructure, each node acts as router to transmit the information. In MANET, each node depends on the other for communication and working in multi hop fashion. Since nodes are operated on battery and random movement of nodes [2], designing energy efficient routing protocol is really a challenging research work. In order to extend the lifetime of network, routing protocol selects the appropriate path by considering various parameters of nodes in the path [3][4]. Wired or wireless routing protocols [5] will not be directly applicable to mobile ad hoc networks due to MANET’s characteristics. Mobile ad hoc networks are invariably applicable in all fields like knowledge sharing applications such as conferences, workshops and rescue operations such as Tsunami, earthquake, flood. In MANET, mobile nodes are operated on battery power and also battery energy has a limited lifetime. So, power availability to mobile nodes is an important resource for operations of nodes. Nodes are depleting their battery energy by participating in communication as node, forwarding the information as router, overhearing the information since the medium is wireless and also exhausts energy even if it is in sleep state. So, battery energy is essentially needed for successful operation of the mobile ad hoc networks. To ensure the effective communication among the mobile nodes, routing protocol will play important role. But, battery energy will also affect the performance of routing protocols. In this paper, the objective of this paper is to discuss the existing routing protocols and various routing schemes for minimum consumption of the battery energy which extends the lifetime of the network.

The paper is organized as follows. Section II presents the major classification of routing protocols. Section III provides various energy efficient routing protocol metrics. Section IV provides the exhaustive discussion of various efficient routing schemes to optimize the existing protocols and section V concludes the paper.

II. CLASSIFICATIONS OF MANET ROUTING PROTOCOLS
The routing protocols establish the path to the destination when no path is available to the source, exchanging the routing information with nodes in the network and broadcasting link error messages if any path breaks in the network. Several routing protocols have been developed to improve the performance of Mobile ad hoc networks. The routing protocols can be classified into the following four types [6].

A. Routing information update mechanism
B. Use of temporal information for routing
C. Routing topology
D. Utilization of specific resources

A. Routing information update mechanism
These routing protocols explain about how nodes are updating the routing information for route the packets and further classified into the following three types.

A.1 Proactive Routing Protocol
A.2 Reactive Routing Protocol
A.3 Hybrid Routing Protocol

A.1 Proactive Routing Protocol
Proactive routing protocols are called as table driven protocols. In this classification, each node maintains routing table for storing the routes to all the other nodes in the network. Each node periodically updates the route information to other nodes in the network to ensure the freshness of route. Source node sends data quickly to destination using routes which are stored in routing table. These types of routing protocols introduce more control overhead as routing information is exchanged at regular intervals. Example protocols: DSDV (Destination Sequenced Distance Vector) protocol, WRP (Wireless Routing Protocol) [3][6][7], Optimized Link State Routing (OLSR) [8].

Optimized Link state routing (OLSR)
In this protocol, selected nodes designated as Multipoint Relay (MPR) are allowed only to transmit the control message instead of all nodes. This approach is helpful to reduce unnecessary control messages which are flying in the networks. In OLSR, each node broadcasts HELLO messages in the network up to two hops distance. Every node can get concrete topology information by getting HELLO message from neighbors and can update the routing table as well as each node is enabled to know its neighbor’s status. Based on information collected from HELLO message each node selects its MPRs. By using MPRs nodes, it initiates Route discovery procedure and starts the data transmission.

A.2 Reactive Routing Protocol
Reactive routing protocols are also called as On Demand Routing Protocols. In this type, source nodes find out the path to destination when they have data to send. In this type, each node neither maintains the routing table nor broadcasts the routing information at regular intervals. In this type, each data packet contains complete route to destination. But these protocols introduce delay to find out the route to the destination. Example Protocols: Dynamic Source Routing (DSR) [9], AODV (Ad hoc On Demand distance vector Routing) [10][11].

Dynamic Source Routing protocol
Dynamic Source Routing (DSR) protocol is an on demand routing protocol which has two major phases to successfully transfer the information. They are route discovery and route maintenance phase. In route discovery phase, source node establishes the route to the destination by flooding RREQ (Route Request). If Source node wants to send data to the destination to which it does not have a route, then source node broadcasts RREQ packets. Upon receiving RREQ packet, intermediating node checks itself for route to the destination. If it has the route then send RREP back to source by adding its own address along with the addresses in the RREQ header. Otherwise, it adds its own address in the packet header and broadcasts the packet. Once packet received by destination in flooding manner, it sends RREP (Route Reply) to the source. Once RREP (Route Reply) received by source, it starts to transmit the data. In network, the node or link may be down due to mobility nature of nodes and nodes are operating on battery energy. DSR protocol handles this problem by broadcasting RERR (Route Error) messages in the network for initiating new route discovery.

Hybrid Routing Protocols
Hybrid protocols combine proactive and reactive protocols and take advantages of these two protocols. Hybrid protocols behave as proactive routing approach if it is in limited range and behave as reactive routing approach if the
A study of recent researches in Energy Efficient routing protocols for battery constrained Mobile ad hoc networks


Fisheye state routing (FSR) protocol is a link state routing protocol which maintains topology information at each node. In FSR, each node exchanges link state information with its neighbours based on time-triggered. FSR does not transmit the entire link state information to nodes which exist too far. Instead, each node transfers within its neighbour nodes only. In this way, FSR ensures minimum control overhead but at the same time FSR does not guarantee the remote nodes.

B. Use of temporal information for routing

These routing protocols use the temporal information to transmit the data to destination. These protocols use the lifetime of wireless links and can be classified into two types based on time. The first uses the past status of link and the second uses the future status of wireless links. Example protocols are Fish state routing (FSR) protocol, Route lifetime Assessment Based Routing (RABR).

C. Routing topology

This classification based on how routing addresses are maintained at each node such as flat and Hierarchical type. Dynamic source routing (DSR) protocol is flat routing type and Fish state routing (FSR) is hierarchical type routing protocol.

D. Utilization of Specific resources

In this classification we will discuss various management schemes for effective use of battery energy of a node. The protocols under this scheme reduce the energy consumption of nodes in order to extend the life of network. Routing protocols efficiently utilizes the resources for routing. Transmission power management manages the transmission power of a node when it transmits a packet. Battery energy management is to extend the lifetime of a node by discharge pattern and type of battery. System power management controls power consumption of hardware parts of a system. System power management is divided into processor management and device management.

III. ENERGY EFFICIENT METRICS OF ROUTING PROTOCOL

Power-aware routing protocols are used to extend the network lifetime [15][16][17]. If a node is down then it does not participate in the communication. So, network will be partitioned which leads to dropping of packets. The power-aware routing protocols consider the energy consumption in terms of network and node levels. In the network level, power-aware routing protocols reduce the total transmission power required to transmit a packet while establish the path. In the observation of node which selects the energy rich nodes while establishing the path and not selecting the energy weak nodes. If we focus on shortest path only, then some nodes in the path will deplete their energy very soon. There are five new metrics proposed to ensure the energy efficient routes for communication.

- Minimize energy consumed per packet
  A node reduces its energy when it is in any one of the states such as send, receive, idle and sleep. If we wish to extend the lifetime of the network, we should conserve energy of each nodes in the network. This metric minimizes the energy consumed by nodes in the network. To achieve this, packets should travel in the shortest path while network is lightly loaded. If the network is heavily loaded then packets should travel in alternative path to reduce collision even if it is introduced to additional hops.

- Maximize time to network partition
  A network consists of a set of nodes in which some nodes are critical nodes which play a vital role in receiving and forwarding the packets. If the network uses few nodes to route the packets in the network due to the shortest path then these nodes are used very frequently. If these nodes are down due to the various reasons then the network will be partitioned. Before sending a packet, analyse the network load and distribute the load into all the nodes to balance the network performance instead of using few nodes very often. If we follow this principle, network can withstand and be useful in some typical applications such as battlefield networks.

- Minimize variance in node power levels
  This metric guarantees that network load should be distributed equally to all the nodes in the network rather than a few nodes are overused. This leads to an early exhausting few nodes in the network. The routing protocols use this metric and distribute the load to all the nodes and try to solve the different power levels in the nodes which extends the lifetime of network.
• **Minimize cost per packet**
  The routing protocol includes this metric while selecting a route to forward the packets in the network and ensures to leave the energy weak nodes. While selecting a routing protocol, a route consists of energy rich nodes and not energy weak nodes.

• **Minimize maximum node cost**
  A routing protocol includes this metric to minimize the cost of a node when routing the packets from source to destination and also minimizes the maximum node cost.

### IV. MANET ENERGY EFFICIENT ROUTING PROTOCOLS

The aim of energy-efficient routing protocols is to minimize the energy consumption [18][19][20] during exchanging of packets between source and destination, to select the energy rich nodes for data transmission and to reduce the flooding of routing information to satisfy the QoS requirements of networks. Next, we will discuss the various energy efficient routing protocols based on various resources [21][22][23].

#### A. Transmission Power Control Approach

In a network, a node could communicate with all other nodes if they are in its transmission range. If a node’s transmission range is too long then its reachable nodes are also high. This node could directly communicate with all other nodes. But, this will introduce more interference during the transmission. If we minimize the transmission range then communication is possible with many intermediate nodes which introduces delay. The Energy efficient routing protocols based on the transmission power finds the optimal route from source to destination in the network with minimum power route.

**Minimum Total Transmission Power Routing (MTPR)**

When source node needs to send data to destination to which source does not have the route, Minimum Total Transmission Power Routing (MTPR) algorithm finds and establishes the efficient path based on the lowest transmission power from source to destination amongst all the possible routes instead of remaining battery energy of nodes. Node needs more transmission power when it sends a packet to long distance node than nearest node. In this scheme, node will change its transmission power depends upon the node’s position.

MTPR will play the role as to select the minimum route which is minimum value of total transmission power of a route compared to all other routes. Standard shortest path algorithms select the route based on shortest distance of nodes. Low transmission power is enough to cover short distance of nodes. This algorithm selects more number of nodes from source to destination. Basically, if a route has more number of nodes then there will be more delay to transmit a packet from source to destination. Due to node’s mobile behaviour and nodes operating on battery energy, this approach is not smart. A new metric is considered to address this problem in the distributed bellman-ford algorithm.

In addition to transmission power, transceiver power is also considered as a cost metric. Each node in the network calculates its cost by addition of transmission power, transceiver power is required from itself to its neighbour and cost from source to itself. Each node transmits its calculated cost to neighbours. Node collects cost from its neighbour and select path with minimum cost from source node to itself. This process continues till destination is reached. This algorithm finds routes with smaller number of hops from source to destination to transmit a packet.

#### B. Load Distribution Approach

The objective of shortest path is to find the optimal route from source to destination in the network by considering the minimum number of hops. If we continue this approach then nodes in the route depletes battery energy quickly which leads to network partition. To avoid this problem, load distribution approach considers network traffic and balance the load to all the nodes rather than some selective nodes. This approach will extend the life time of network by sharing the network load to all other nodes in the network. This section will discuss some of the load distribution schemes routing protocols as follows.

**Minimum Battery Cost Routing (MBCR)**

MBCR considers the route selection for data transfer in the network in terms of node battery cost function. If a routing protocol selects a route with nodes based on a function of node’s remaining battery capacity, MBCR will select a route with battery cost function value which is inversely proportional to the residual battery power of a node. Nodes collect all possible routes combining nodes with battery cost function. Moreover, this scheme incorporate battery capacity directly in routing algorithms, it helps the energy weak nodes free from data transmission. If the routes have nodes with same battery capacity, this scheme will select the shortest path. This
A study of recent researches in Energy Efficient routing protocols for battery constrained Mobile ad hoc networks

scheme ensures to extend the network lifetime because it always selects a route combining the nodes whose remaining battery energy is high.

**Min-Max Battery Cost Routing (MMBCR)**

In MMBCR, a source node wants to send data to the destination to which source does not have the route, source broadcasts Route Request. After getting first Route reply from destination, MMBCR enables the source node and waits for some more Route Reply from the destination to choose the best route. Source node selects a route which consists of nodes which are energy rich nodes. MMBCR will consider residual energy of all the nodes in the routes and helps to extend the network lifetime. While selecting energy rich nodes route, sometimes it may be include some additional hops.

**Conditional Max-Min Battery Capacity Routing (CMMBCR)**

Conditional Max-Min Battery Capacity Routing (CMMBCR) [24] combines both the total transmission energy consumption of routes and the remaining battery capacity of nodes in the route and considers individual node’s battery capacity. CMMBCR combines characteristics of MTPR and MMBCR schemes as well as CMMBCR uses battery capacity instead of battery cost function as a metric for route selection procedure. CMMBCR assigns some predefined value as threshold value to remaining battery capacity of a node. If node’s residual battery power is greater than it is energy rice otherwise it is energy weak node. When source node receives more than one rich path, CMMBCR selects the one rich path which consume minimum transmission path compared to other routes.

**C. Sleep/ Power-down approach**

This approach concentrates the devices during inactive time of communication. This approach makes the radio sub systems of nodes as sleep instead of active during the idle time to reduce the power consumption. In this scheme, one node acts master and its neighbor nodes act as slave. Slave nodes are wake up for equal period of interval and checks during equal period of interval slave nodes wake up and communicate with master for any packets received for it. It sends reply and again goes to sleep state and wake up after some period. In MANET, communication is possible in multi hop fashion so that slave nodes are periodically wake up and assists for communication. Example protocols: SPAN protocol [23] and Geographic Adaptive Fidelity (GAF) protocol.

**SPAN Protocol**

SPAN protocol employs rules for selecting the node as master in mobile ad hoc networks. In this protocol, a node will become master if its neighbors could not reach by directly. Master node collects packets and stores them and provides the communication on behalf of its neighbors. Master communicates and provides the information to slave nodes when it gets wake up. SPAN protocol employs a rule to ensure the master node free from early dead since master is also working on battery energy. All nodes will get master place based master eligibility in order to share the network load and avoid early dead state.

**D. Review of Recent development routing protocols**

Energy Dependent DSR (EDDSR) [25] is DSR based routing protocol which is a power aware routing algorithm. EDDSR is basically works based on the battery energy of nodes in the network and also extend the lifetime of network. In this protocol, each node computing its energy and decide whether to participate or not in the transaction. Predicted lifetime of a node can be calculated by its residual battery power and drain rate [26]. By using this, we could estimate the lifetime of a node in the network. EDDSR frees the energy weak node from participating in route discovery procedure to avoid the early death of node and network partition and to extend the network lifetime. In fact, it is more likely that the RREQ sent from a node with a small predicted lifetime will be dropped by the nodes closer to the destination since in the DSR protocol intermediate nodes only forward the first received RREQ.

The EDDSR mechanism also modifies the route maintenance process of the DSR protocol. When the energy of a node along an active route falls below a critical threshold, it will immediately inform the source by sending a RERR packet. The source will try to find another route to the same destination by initiating another route discovery process. The critical node will be more reluctant to participate in the forwarding activities of a new route to the destination. Finally, the EDDSR algorithm makes use of the route cache in a similar manner suggested by the LEAR protocol. Thus, the RRCAC message is processed by the intermediate nodes is the same manner as the RREQ.

Load Aware Routing in Ad hoc (LARA) [27] is another routing protocol for wireless ad hoc networks. In LARA, source node broadcasts Route Request packet to initiate route discovery procedure. Intermediate nodes receive the route request and forwards Route Request if it does not have the route to destination. When Route Request arrives at the destination, the destination node chooses the route by considering hop length, cost needed to transmit a packet by nodes in the route and delay introduced by each node in the path.
The Minimum Drain Rate Mechanism (MDR) [28] is used to estimate the lifetime of the nodes. The lifetime of node depends on forwarding and processing the data as well as the residual battery power. MDR is working based on the Min-Max Algorithm. Source node broadcasts Route Request when it does not have a route to the destination. Intermediate node receives Route Request and adds its current residual energy in Route Request. After updating energy value, intermediate node forwards the route request. Destination node receives the Route Request packets from all routes for a time period. After timeout, destination node apply Min-Max algorithm in the received request to selects the route and sends Route Reply (RREP) to the source. In MDR, intermediate nodes are not allowed to send RREP to the source instead of the destination. Source node broadcasts a packet to know about the current energy of the nodes. This scheme will be useful to allocate the load to the nodes in the network. MDR is purely based on either source or destination to make routing decision to establish the route.

Distance routing effect algorithm for mobility (DREAM) [29][30] is proactive routing protocol as well as location based routing protocol. DREAM enables each node maintaining routing information in the routing table. In this protocol, each node periodically broadcasts its location information to all other nodes as control messages. Source node is always having fresh route information to the destination. Based on this, source selects a set of one hop neighbours which existing in the path to the destination.

While sending data to the destination, source encloses the list of nodes’ information in the data header. If no neighbour existing then source broadcast the packet. DREAM ensures the nodes which are in the list only are allowed to receive and process the packet. Next, these nodes select next hops towards the destination and enclose the updated list while sending the data. If destination node receives the data then sends an acknowledgement (ACK) to the source in the same manner but with exemption ACK is not flooded intermediate the network. Otherwise, if no neighbors are existing then packets will be dropped. Alternatively, source selects set of nodes and transmits a packet by setting timer. Source re send the data in the flooding manner when source does not receive ACK within timer expired.

Stability-based, QoS-capable Ad-hoc On-demand Distance Vector (SQ-AODV)[31] establishes the route when enough nodes in the route and when nodes as well as routes are with maximum residual energy. This feature ensures that route will not break due to the energy depletion and satisfies Quality of service. Finally, when the RREQ packets reach the destination, it picks a route that maximizes the route life-time by selecting the one with maximum life-time of the bottleneck node. The second feature ensures when a link break due to node energy depletion is imminent, SQ-AODV proactively re-routes sessions, without losing any packets. Once again, this provides near-zero packet loss and superior QoS performance. The source broadcasts Route Request (RREQ) packets to its neighbours when it has no route to the desired destination. When a RREQ packet reaches an intermediate node it checks its residual energy. If it is above the Threshold-1 value then it allows processing the received Route Request packet. If the node’s energy is less than value then that node is restricted from processing the request. When the RREQ packet arrives at the destination, it selects a route with maximum route life-time from other routes. When node is in data transmission SQ-AODV make aware the node to continuously monitoring the residual energy. If the energy goes below the Threshold-2 value then node sends a Route Change Request (RCR) packet to all source nodes to make necessary action either reroute the packet or rediscover the route to forward the data.

Radwan S. Abujassar et. al [32] proposed a scheme is called Alternative Routing Table Short Distance (ARTSD) which improves the performance of table driven routing protocol like Destination sequence Distance vector protocol performance by maintaining multipath such as primary and backup route. This protocol selects a backup adjacent node regarding with the original routing table and enables each node to predict the second shortest path from source to destination node. This scheme enables node to use the alternate route when there is a breaking of the link. Source node selects any one neighbor which is excluded in the primary route and designated it as backup node to redirect the packet when primary routes are down. This protocol ensures all the nodes that to maintain the routes to all the destinations and enables the node to send the packets using backup route. In this scheme, each node on the primary path connects with adjacent nodes to reroute the data packets. This protocol ensures that alternative route is disjoint route from primary one. In this algorithm, distance between the adjacent nodes in the radio propagation range is calculated. This algorithm selects node whose distance is less than 250m as adjacent node. If more than one node exists then select a node which is disjointed path to destination.

Adhoc on-demand multipath distance vector (AOMDV) [33] routing protocol provides multiple paths in the way of link disjoint paths. In MANET, link may be broken due to either nodes operating on battery or mobility of node. Either intermediate node or source node will initiate the route discovery procedure to find out the path to destination to continue the transmission. To start the route discovery procedure nodes consumes energy to process control messages which aid to route discovery procedure. But if a protocol has multiple paths then source node continuously
A study of recent researches in Energy Efficient routing protocols for battery constrained Mobile ad hoc networks

transmits the information. In these multipath schemes, route discovery procedure will be initiated when all routes are down. This protocol has two main parts like there are multiple loop-free paths at each node in the networks and a distributed protocol which finds link-disjoint paths from source node to destination node in the network.

Energy Saving Dynamic Source Routing (ESDSR) [34] is a modified version of dynamic source routing protocol which combines both the advantages of a transmission power control and load distribution approach to ensure the lifetime of the network. ESDSR works similar to DSR with some modifications. ESDSR uses minimum transmission power control approach to select a route from the set of routes by a source node. In ESDSR, source node select minimum transmission power path to send a packet to closer nodes in the network. In ESDSR, all the paths are assigned with score value. Score value is the ratio of the remaining battery energy and current transmit power of a node in the path. Source node broadcasts Route Request (RREQ) to find the route to the destination. ESDSR enables the nodes to include their energy level while forwarding the packets in the network. By receiving nodes update their corresponding entry with current energy level of nodes in the network. Source node collects all the routes from the network and selects a route based on the score. Each path is assigned with score value of the nodes in that path. ESDSR first selects the lowest hop energy of each path. If there are multiple paths are existing then maximum of lowest hop energy of the path is chosen to transmit the packet from source to destination.

Weight based Dynamic Source Routing (WBDSR) [35] protocol an improvement of conventional DSR protocol. In this protocol, the route will be selected based on route weight metric. Weight of each route can be calculated by Calculating the node weight based on battery level of this node and Stability of this node. From the collected information, route weight can be calculated as minimum of all nodes weights in this route. WBDSR selects the best route as minimum route-weight considering the minimum of all node weights included in this route. This protocol will select the main route as which is maximum route-weight. When more than one route has the same route-weights then this protocol will choose the route which has minimum number of hops.

Energy-Efficient Location Aided Routing (EELAR)[36]: Energy Efficient Location Aided Routing (EELAR) Protocol is the optimization of Location Aided Routing (LAR) protocol. EELAR protocol reduces the energy of mobile node to find out the path to destination. In this protocol, a wireless base station acts as server to cover certain area. Current positions of mobile nodes are stored in this base station. If source wants to find out the route to destination it sends RREQ to base station instead of broadcasting RREQs. This approach will be helpful to reduce the excess control overhead. Source node will get route from the base station. The base station stores locations of the mobile nodes in a position table.

V. CONCLUSION

The paper has made brief survey of existing routing protocols and optimization schemes to improve their performance in such a way that nodes consuming minimum energy ensure the extension of network lifetime. Mobile Ad hoc network, an efficient routing protocol establishes the route from source to destination in multi hop fashion. When choosing a route, a routing protocol should consider the various constraints such as residual energy of nodes, shortest path and bandwidth. Since, Battery Energy of nodes plays a significant role in affecting the performance of Routing protocol in many situations as seen in this paper. Moreover, various energy efficiency routing protocols which increase the lifetime of network explained. Based on this, we conclude that each protocol is proposed with its own objectives for certain scenario. So, the work is needed to propose an energy efficient routing protocol for effective utilization of battery energy of nodes and meet the rapid development of mobile devices.

REFERENCES