CHAPTER 3

LITERATURE SURVEY

3.1 INTRODUCTION

Energy efficient routing algorithms can be broadly categorized into three areas as energy saving at node level by power sleep on/off condition, routing based on total energy expenditure, and dynamic topology control of nodes (Chi & Yang 2000). On the vision of effective communication, the principal goal of energy efficient routing in mobile ad hoc networks lies in establishing a correct and efficient route between a pair of nodes so that information can be delivered reliably and in a timely manner to fulfill all the basic requirements of successful communication. And also routes construction should be carried out with minimum overhead and bandwidth consumption.

Due to absence of central coordination or base stations in MNAET, the aspects of routing the nodes becomes much complicated. In MNAET, the routing and resource management are carried out in a distributed manner. Communication among all nodes is made possible by coordinating the functions of all nodes. In a communication network, the functions of transmission, reception, and routing from one node to another node in the network are crucial and these are fundamental requirements to accomplish effective communication. Each node is designed in a precise manner. Routes from source to destination or between intermediate nodes in the network are
usually determined on the basis of end-to-end packet traversal energy consumption.

However, energy efficient routing cannot be so worthy without considering the key factors for effective communication like reliability, residual energy of nodes etc. Reliability in one way relates to security for improving the quality of communication and taking into consideration of residual energy unnecessary overusing of nodes can be avoided. So, there is a chance to increase the lifetime of the network.

A lot of techniques and algorithms for energy efficient routing using various procedures like dynamic transmission power adjustment (Stefano et al. 2007), directional antenna, adaptive sleeping, multipath routing, topology control, etc., have successfully been put forward for enhancing the basic requirements of ad hoc networks namely energy efficiency, reliability and lifetime of network and so on. On account of emphasizing one of the basic requirements, the designer tends to compromise with the other requirements without contention. But, it is better to have a balanced approach about everything to realise effective communication.

The reason behind success of some basic wishes and failure of other needs is lack of attention on integrated approach in designing the protocols and algorithms for routing the nodes in the network. Indeed, integrated approach is a much challenging task in MANET. But there are promising opportunities to produce energy efficient routing and effective communication by adopting an integrated approach. For energy efficient routing, it is necessary to modify the existing routing protocols and algorithms to meet the present and forthcoming challenges.

Energy management in mobile ad hoc network can be defined as the process of coping with the available sources in the network and
consuming of energy in a node or in the whole network at full swing for maximizing the network lifetime. This can be predicted in relation to present traffic situation by several mechanisms. Energy management involves many functions as designing the discharge pattern of battery used in the nodes for enhancing the battery existence, finding the best route at the time of operation that consumes minimum total energy in the network, dealing the processor and interface devices to reduce power consumption and it is so important in MANET because of restricted energy reserve, lack of central coordination, constraints on the battery source, complications in replacing the batteries, selection of optimal transmission power and channel utilization.

The energy efficiency of a node in the network lies on its ability to deliver how much amount of data with respect to total energy consumption. After all, the ultimate aim is to avoid unnecessary operations and also ensure optimum utilization of all the resources brilliantly with respect to energy consumption. Besides, all the functions should be alive for effective communication both at active and inactive states of nodes in the network. Normally, on the view of various applications used in the MANET, multipath energy efficient routing has got much preference because it keeps up reliability, efforts to minimize delay of traffic, energy conservation, and conforms to bandwidth requirements. To consider all the above aspects, energy efficient routing for effective communication is experimented by adopting any one of the following methods:

- Shortest Path Metrics Methods
- Transmission Power Control Methods
- Load Distribution Methods
- Sleep/Power Down Methods
Some of the shortest path method, transmission power control methods, and load distribution methods are employed to reduce energy consumption at active stage of communication. On the other hand, sleep/power down methods and some of the shortest path metrics are used to lessen energy consumption at inactive stage of communication.

3.2 SHORTEST PATH METRICS METHODS

The solution for energy efficient routing lies in the application of shortest path metrics. In spite of it having some demerits and considering other positive aspects, the shortest path metrics provide fair solutions in numerous cases for effective communication. The two renowned shortest path algorithms are Dijkstra and Bellman-Ford algorithms. The former algorithm is implemented in a centralized manner whereas the later one is implemented in the distributed manner to find the shortest path between various nodes in the network. Bellman-Ford algorithm shows slow rate of convergence than Dijkstra algorithm. But it is more versatile. And before getting involved into design of shortest path from one node to another node in the network, variety of path problems should be considered. Some of them are discussed as below:

- Most reliable delay constrained path: For every link of the network, we can assign or measure a delay value and a reliability value that are to be known at the time of processing. And the end-to-end delay can be calculated as the sum of link delays along the path whereas path reliability as the product of link reliabilities. Through these metrics we can identify the most reliable path in the network.

- Least vulnerable path: In the network measuring some links is jeopardized by some attack and those links may fail at the time
of operation. So it is better to either avoid those links or incorporate minimum number of links.

- **Minimum exposure path**: In the network domain, some nodes are vulnerable for attack or they are in an embattled position. So, when finding a path to destination, we must keep away from those nodes as far as possible so that there will be the minimum chance of attacking or jamming.

- **Maximum data volume path**: For each node in the network, we must evaluate how much data it can handle and lifetime prediction for each link. Hence, we can choose the path based on the capacity of data to be processed. In this path, handling data traffic is the key issue.

- **Path with maximum number of round trips**: If delay value and estimated lifetime for each link are known, we can make best use of it between the ultimate source and destination nodes or intermediate nodes in the network for delay calculations to afford better communication.

- **Minimum energy path**: Generally in mobile ad hoc networks, batteries are designed to consume less energy most preferable. It has a lot of merits. But, the negative aspect of this scheme is that it limits its performance. So, many brilliant efforts are taken to reduce energy consumption without affecting other factors for effective communication while at on and off stages of processing nodes in the network. Minimum energy path in routing normally concentrates taken into account how much of total energy is consumed on overall operation of communication.
between two nodes in the network and focuses on avoiding unnecessary consumption of energy.

- Maximum battery lifetime path: In addition to minimum energy path, we can include the battery aware routing for maximizing the lifetime of battery used by the network. To improve the lifetime of battery at nodes always depends on minimum energy consumption. Minimum energy path influences maximizing battery lifetime. Besides minimum energy path, other factors like residual energy at each node, impact of effective communication, node’s transmission and reception capacity also contribute to improve lifetime of network.

Energy aware reliable routing: In energy efficient routing mechanism, energy consumption cost of a path is considered and is directly interconnected to its reliability. Without reliability at the destination node, it is not possible to reduce the probability of packet retransmission. If packet transmissions are more, minimum energy consumption could not be ensured. So, in the design of energy efficient routing, the energy cost of a route between a source node and a destination node must be evaluated. When analysing energy cost of a route, various factors like reduction on energy consumption per packet, reduction cost per packet, maximizing time to network partition, minimizing maximum node cost, decreasing variance in node power levels, expected transmission count of data and acknowledgement packets, link and path reliability, total energy consumption across a link, residual energy and so many things regarding this issue are taken into account.

Energy Delay aware based Dynamic Source Routing (ED-DSR) was proposed by Rekik et al. (2011). It deals with the demerits of choosing
the shortest path to reach the destination in real time situations with respect to energy efficiency and reliability within confined limitation and tries to fulfil the basic objectives of shortest path selection. The basic scheme exercised here is Dynamic Source Routing with energy delay awareness which is extremely useful for utilizing network resources.

Genetic algorithms based heuristic approaches provide solutions to reduce the energy consumption in MANETs. Muhammad & Gianni (2010) proposed such an approach using Ant Colony Optimization (ACO) in routing protocols. ACO is based on the natural behaviour of ants; it finds the shortest route by depositing pheromones in their food. These approaches are rugged with respect to the dynamic topological changes, which are characteristic of MANETs.

Yang Qin et al. (2007) implemented the Power and Traffic Balance Awareness Paths Selection Routing Scheme (PTPSR) in which finding into account the shortest path and power conservation are approached in a combined taking on awareness of energy and load. Here the key issues are power conservation, shortest path and traffic load balance. The results show that PTPSR produces a better performance.

3.3 TRANSMISSION POWER CONTROL METHODS

Generally, the primary function of energy efficient routing in MANET is to find the route that is most favourable in all aspects like energy consumption, security etc., for effective communication at active state. Transmission power control methods are adopted to minimize energy consumption at active stage of communication and to enlarge coverage area which is directly connected with transmitter power of the node that has great impact on reach-ability of the node. Depending on the transmitter power of the node, the coverage area may be larger or smaller. The reachability of the
node is also influenced by the transmitted power of the node. These methods are able to influence the bit error rate, transmission rate, and inter radio interference in wireless ad hoc networks. If proper methodology is adapted to control regarding power levels of nodes in the wireless MANET, there are a lot of chances to save power and to avoid unnecessary wastage of energy. To achieve optimum transmission range, the following schemes are generally prescribed:

- Dynamic power adjustment policies
- Distributed topology control algorithms
- Constructing distributed power control (Sharad et al. 2001) loop
- Centralized topology control algorithm

There are many transmission power control methods (Gomez & Campbell 2007) exercised in MANET, such as Flow Argumentation Routing (FAR), Online Maximum Minimum routing (OMM), Power aware Localized Routing (PLR), Minimum Energy Routing (MER), Retransmission energy Aware Routing (RAR), Smallest Common Power Routing (SCPR). All the said methods focus on minimizing total energy consumption and some of them from avoiding low energy nodes so as to consider retransmission overhead instead of taking bi-directionality factor and so on.

A new MAC layer protocol called Slow Start Power Controlled Protocol (SSPC) has been developed by Emmanouel et al. (2009). In this, RTS/CTS and DATA frame transmission are improved using power control in IEEE 802.11 (Ming Liu & Liu 2003) for reducing energy consumption which can be obtained by adopting the node transmission power control from minimum to reliable reception at the destination node whereas network throughput is obtained by allowing more transmission simultaneously. SSPC
reckons collisions free path and DATA frames transmission power. SSPC is achieved better energy consumption.

Rui Yang et al. (2010) have proposed MAODV (Multicast Ad hoc On-demand Distance Vector) routing protocol. It provides a route establishment between two mobile nodes in a fast and efficient manner. The key idea of Energy Entropy-based multicast routing protocol in MAODV (EEMAODV) protocol is to be found out using minimal residual energy for establishing a path between nodes. Hence, it concentrates on battery power consumption and henceforth prolonging the network lifetime. Simulation results reveal that EEMAODV performs well than MAODV.

Eun-Sun & Vaidya (2002) introduced a power control schemes using different power levels for RTS-CTS and DATA-ACK. Power level usage for RTS –CTS and DATA-ACK can be dynamically adopted while transmission and throughput is reasonably increased. It allows using maximum power for RTS-CTS and adequate power level for DATA-ACK transmissions.

Wang Bo et al. (2009) have proposed a novel routing protocol. It is based on an energy model in ad hoc networks. It makes to make best use of lifetime of the network, by way of efficient power consumption and total energy consumption. An efficient routing protocol should perform both even distribution of energy consumption and minimization of total energy transmission for every request simultaneously and without giving priority to any of them. So, a good trade-off is exercised between them for getting better performance.

Garcia et al. (2003) have proposed a novel DSR-based energy-efficient routing algorithm referred to as the energy-dependent DSR (EEDSR) that put off unnecessary battery energy consumption. EEDSR is contrasted
with the recent notified mechanisms of Least Energy Aware Routing (LEAR) and Minimum Drain Rate (MDR). EEDSR approach to establish a route that is purely based on less amount of power consumption. It is comparable to least energy aware routing and minimum drain rate mechanism and provides a balanced approach at one step ahead considering power consumption.

Savazzi & Spagnolini (2007) have proposed methodology, is based on the optimization of transmitted power in a cooperative decoded relaying scheme approach. Multihop Cooperative Transmission Chain (MCTC) is transmission protocol which is used here to determine the routing along the terminals in order to maximize the multihop diversity. In this approach, the problem of allocating the transmission power is invented among cooperative relaying nodes when the route has been optimized separately. Here the sequence of messages is continuously transmitted by a source node to destination node over an optimal connection oriented unicast route path. The power allocation for MCTC is inherently recursive and the route selection is based on different metrics such as end-to-end delay and packet throughput.

3.4 LOAD DISTRIBUTION METHODS

Load distribution methods are involved in active state of communication in the network and used to avoid congestion of data packets for travelling well to the destination from source. It prevents from being overloaded of the nodes with balanced approach and well suited for large networks.

Energy efficient routing with load distribution approach ensures maximizing network lifetime as well as reliability of data transfer. The important goal of energy efficient routing design is to spread out the routing assignment to all nodes in the network in a brilliant manner. Shortest path energy efficient methods are generally considered as optimum routing
solution. Load distribution methods are used to rectify the drawbacks of shortest path energy efficient routing like blocking of data’s, power reduction, and queuing setback. There are a lot of energy efficient routing approaches on the view of load balancing and some of them are adapted in general manner whereas few others are adapted for particular environment only. Localized Energy Aware Routing (LEAR), Conditional Maximum Minimum Battery Capacity Routing (CMMBCR), Type of Service and Load Aware routing protocol (TSLA) and Load Sensitive Routing (LSR) protocol are some of the examples of load distribution methods.

The major problem in geographic routing is packet reception at the receiver or at another node in the network which is reflected in the network lifetime. Wang et al. (2010) have proposed energy efficient and load balanced geographic routing (ELGR) algorithm using routing decisions. First, the link estimation of packet reception is performed for enhancing network energy efficiency, and then, the load balanced method is applied to ensure the use of the whole network. The simulation study results reveal that ELGR performs better than other geographic routing schemes with an increasing network lifetime.

Qing Zhao et al. (2007) have proposed an algorithm namely Energy-Aware Geo-location-aided Routing (EAGER). It is based on a hybrid routing protocol. It involves topology-based technique. The routing protocol divides the network into different proactive cells based on self-location information. It minimizes the number of nodes participating in the route discovery process and transmission range. It uses RAS (Chiasserini et al. 2000) to awake the sleeping node to actively communicate. The performance of EAGER shows that it has better energy efficiency than that of Zone Routing Protocol (ZRP).
An Energy-Efficient On-Demand Routing Algorithm for Mobile Ad-Hoc Networks has been developed by Dhurandher et al. (2008). In this method, energy consumption among various nodes in the network is balanced to enhance the network consistency. Energy Efficient Ad hoc On Demand Routing (EEAODR) algorithm provides a balanced approach on consuming energy among various nodes in the network.

Routing algorithm based on ant colony optimization provides the keys to overcome the drawbacks of other position based-routing algorithms in the mobile ad hoc networks. As it handles a huge amount of control messages, but, a lengthy delay before establishing a route between source and destination occurs. Kamali & Opatrny (2008) have developed a Position Based Ant Colony Routing Algorithm (POSANT) which uses ant colony optimization and node’s position information to establish a route between nodes, with minimum number of control messages and less route establishment time.

Power Saving Routing Protocol with Power Sieving (PSRPS) has been implemented by Wu & Tuan (2009). It makes an attempt to save power by dividing the network area into many square grids with the aid of location information. In PSRPS, one node is elected as the grid leader in its grid with power sieving mechanism without broadcasting election packets. This mechanism adds some benefits in traditional grid based routing protocol for reducing power consumption as well as improving the network lifetime.

Energy Saving Cache-based Routing protocol (ESCR) has been introduced by Yi-Chao Wu & Chiu-Ching Tuan (2007). Here the whole network is divided into grids of side, d. One of the nodes in the grid is elected as grid header whose transmission power is given as, r. Only the grid header is capable of relaying the packets into the network. The grid header is changed if its transmitting power is not sufficient. This election process is
modified from the traditional method so that all the nodes need not wake up periodically for the registration process. Each node in the grid maintains a table. This table contains columns of grid coordinates, node identities and the energy remaining for all the nodes in the network. The node with higher energy is elected as the grid header. Then the header energy is decreased appropriately. Once its energy becomes less than sufficient energy, the next member in the grid with highest remaining energy is elected as header. The routing is carried out in two levels, inter and intra grid levels. Route maintenance is done with the help of energy threshold. Thus this method gives 20 % more life time and 24 % more survival ratio.

3.5 SLEEP/POWER DOWN METHODS

Sleep/Power down approaches give much attention to save energy of nodes in the network during inactive stage of communication. In this approach master/slave concept is applied in an asynchronous fashion. During communication period all nodes in the network do not necessarily involve. It is good strategy to save power of the remaining nodes during that stage. Span, Geographic Adaptive Fidelity (GAF), and Prototype Embedded Network (PEN) are some of the examples of sleep/power down schemes.

Energy-related metrics have been used to determine energy efficient routing path instead of the shortest path before designing protocols that belong to different approaches. They are as follows:

i. Energy consumed/packet,

ii. Time to network partition,

iii. Variance in node power levels,

iv. cost/packet, and

v. Maximum node cost.
Mobile Ad hoc Networks are characterized by a dynamic topology that can change topology frequently due to MANET’s mobility. Efficient routing protocols are needed to establish communication paths between nodes, without causing excessive control overhead or computational burden on the power constrained devices. Many energy saving routing protocols have already been proposed (Feng Zhenxin & Li Layuan 2008). A number of proposed solutions attempt to have an up-to-date route to all other nodes at all times. To this end, these protocols exchange routing control information periodically and on topological changes.

In this section various energy saving routing schemes and methodologies followed earlier by different researchers to overcome certain issues in the mobile communication are presented.

Neeraj et al. (2011) have reviewed the power-saving protocols. The idle nodes enter into low power state, i.e., a node is in sleep state. The node periodically listens to whether any packet is intended for it. Data traffic is buffered for sleeping neighbours at the Media Access Control layer and are routed only by non-sleeping neighbours. Various methods, such as the Basic Energy Conserving Algorithm (BECA), Adaptive Fidelity Energy-Conserving Algorithm (AFECA) (Xu et al. 2000), and Span (Chen et al. 2002) are examples of such protocols. These, in strict sense, are only energy saving algorithms and not routing protocols as such. These algorithms are used in conjunction with existing routing protocols to obtain precise results.

AFECA is a power-save approach. It has been developed by Ya Xu et al. (2000) and used with the routing protocols. It provides a procedure to select the idle nodes and rotate nodes into the sleep, listen and active states. AFECA is the enhanced form of Basic Energy-Conserving Algorithm (BECA) with a new sleep interval based on neighbours. Energy saving is achieved by changing the states of the nodes periodically.
Benjie Chen et al. (2002) have introduced an energy saving technique called Span. It adaptively selects coordinators from the network from among all nodes. It rotates the coordinator role among nodes to balance the energy savings. Thus, coordinators act as backbone routers for the whole network and provide guaranteed connectivity by ensuring that at least one active node is in the coordinator’s range. The coordinators are selected based on their remaining energy and the utilization of the node. If two nodes cannot reach each other, those nodes become a pair of coordinator nodes, which produce better throughput and energy efficiency.

Ya Xu et al. (2001) have implemented the Geography-informed Energy Conservation (GAF) algorithm for conserving energy, based on location information obtained through GPS. In this approach, the whole network is divided into virtual grids of minimum size. Communication between the neighbouring virtual grid nodes is present. Energy saving is achieved by a power-save technique and placing the nodes into the sleep state. The nodes are in three states, namely, route discovery, sleep and active. The states are rotated to balance the residual energy in a distributed manner. The node stays in the active state for a random time interval and then enters an energy-saving state.

SPAN and BECA/AFECA is a power saving approach (Kristensen & Bouvin 2008). This is based on the idea of connected dominating sets. It employs two energy preserving techniques such as Basic Energy-Conserving Algorithm (BECA), Adaptive Fidelity Energy Conserving Algorithm (AFECA), are worked together with Re-active routing protocol AODV for establishing a new energy efficient routing protocol. These two techniques can dynamically handle switching between ON/OFF states of the nodes. It can be tuned to forward usage of nomadic network.
Gossip-based Sleep Protocol (GSP) has been proposed by Xiaobing Hou & David Tipper (2004) for synchronous and asynchronous networks. The system uses the random nature of nodes in the network. This is a discretional probability approach based on sleep modes. Other features are its simplicity, scalability and connectivity. Each node is assumed to go for sleep state at random manner for some time. Each node changes its state into the sleep state for a random time interval based on the gossip probability P, which in turn reduces its energy consumption.

Rajeswari & Venkataramani (2012) have proposed a modified protocol which reduces the energy consumption by probability for a sleep node based on packet delivery ratio at destination. According to this protocol, every node in a network maintains a control buffer B, which represents the number of current active neighbours. Hence power efficient nodes are selected and path is established by broadcasting the route request packets. Thus the date packets are delivered in the estimated path. To make the communication more reliable Remote Activated Switch (RAS) is embedded at each node. Whenever the intermediate node becomes inactive, the standard receiver/transmitter is turned off and waking up signals are sent and demodulated by RAS. Therefore nodes in sleep state are triggered to active mode. But when the packet delivery ratio is greater than the threshold value then the intermediate nodes are triggered to sleep mode.

An enhanced power saving contention free algorithm has been proposed by Ming Liu & Liu (2003). This protocol makes use of beacon messages. Single hop networks are used in 802.11 and they are referred to as Independent Basic Service Set (IBSS). Time Synchronization Function (TSF) and power management functions are incorporated here. Hence each node moves to the Power Save (PS) mode when it is idle. As per TSF, each IBSS consists of a parameter called beacon period. After beacon broadcast, Ad hoc
Traffic Indication Message (ATIM) window is defined with a fixed number of slots. If a station has some buffered packets for another station, it tries to send an ATIM packet to the destination station and lets it to be aware of incoming traffic. The ATIM window size should be approximately 1/4 of the beacon interval. All stations in IBSS stay awake from the start of the beacon interval till the end of the ATIM window. After successful transmission of ATIM packets, the data packets are delivered to the destination as per sequence specified in ATIM window.

Terry Todd et al. (2000) have proposed the RFID Wakeup for embedded wireless networks. Obviously, these types of systems have to be followed low power technique for power consumption. Scheduled rendezvous power saving technique utilizes low power wakeup mechanism which depends on low power radio circuit that is activated whenever communication is demanded by the nodes. Scheduled rendezvous power saving techniques works very well in hybrid domain of wireless ad hoc networks.

Gossip Routing Protocol has been introduced by Rajeswari & Venkataramani (2010). It is a slight enhanced version of reactive MANET protocol. Route Request messages are broadcasted here; but however redundancy is reduced to avoid collision and thus energy is saved. At the initial stage, the protocol fixes the nodes which need to be in an active mode with probability p or in a sleep mode with probability 1- p. Counter B is set at each node which represents the current number of neighbours in an active state. The value of B is adaptively adjusted based on the packet delivery ratio. For high packet delivery ratios, a node adapt to low-powered transmissions and for low packet delivery ratios, it is vice versa. Since GRP consumes power based on packet loss ratio, it maximizes the lifetime of the network and minimizes the energy consumption.
3.6 OTHER POWER AWARE ROUTING PROTOCOLS

An Energy-efficient DSR Routing Protocol based on Mobility Prediction has been introduced by Yuhong Luo et al. (2013). Energy efficient DSR routing protocol, which emphasizes mobility prediction of the nodes, gives much priority to energy efficiency while selecting the route to the destination. This protocol shows good results in lifetime of node and competence in data forwarding.

Said Khelifa & Zoulikha (2010) have modified the AODV protocol and named it as Energy Reverse Ad Hoc on Demand Distance Vector Routing (ER-AODV). It uses two mechanisms viz., multiple route reply and residual energy when at route selection in basic AODV protocol. The main objective of modified AODV protocol is to provide a path from source to destination with less number of route requests and restrict large number of retransmissions. Result shows better power consumption of battery.

Distributed Energy Efficient AODV Routing protocol (DEEAR) has been proposed by Joshi & Rege (2008). It offers a good trade-off between less and fair energy consumption for maximizing the network lifetime with less control packets. DEEAR improves network throughput as well as data packet delivery ratio.

Goyal et al. (2010) has proposed power control loop which is usually employed in cellular Code Division Multiple Access (CDMA) networks. A wide-ranging simulation background is exercised such as group mobility, group communication and terrain blockage models to strengthen the proposed idea. The results show a fair result to less energy consumption in ad hoc wireless networks and discharge the expectations of future development.
Rong Zheng et al. (2003) have reviewed different wake up mechanisms and formulated a mechanism for power management. Here, an asynchronous wake up protocol is suggested into three parts, neighbour discovery, prediction and reservation. Though the present circumstances on power management are not congenial to support in the line of time limit communication on the presence of network partition, clock synchronization, and other related dynamics, the proposed protocol has been intended to evaluate from the present level to an idle level in power management procedures. And it can be appropriate for both symmetric and asymmetric communication model. Energy saving can be as high as 70%, while the efficiency of data communication is minimally affected.

Energy-Efficient OLSR (EE-OLSR) has been introduced by De Rango et al. (2008). In this protocol, energy consumption is improved by modifying the minimum drain rate selection mechanism. This mechanism incorporates willingness concept and exclude the overhearing energy. By this way the network lifetime is prolonged. Comparison between EE-OLSR and basic OLSR is performed with well-known energy aware metrics such as MTPR, CMMBCR and MDR. EE-OLSR gives better performance in intense traffic.

Jeng et al. (2007) have introduced a modification in AODV routing protocol by applying energy Efficient Geographical Routing (EGR) to find relay nodes under relay region to lessen energy consumption. The radio propagation model works on energy proportional principle to balance the traffic and relay region. It elects the relay node with the highest remaining energy. EGR can abide to follow any kind of routing protocol in wireless networks and perform well under low mobility condition of nodes in the network.
Guan-Nan Chen et al. (2006) have proposed a Multi-Hop Time Synchronization Protocol (MTSP) based on IEEE802.11 ad hoc mode. This protocol attempts to achieve time synchronization in multi-hop MANETs. MTSP works on two stages. At first stage named as beacon window forming a synchronization group with the ability to directly communicate with each other and selects a leader which has the fastest timer among the group members. And on the second stage termed as synchronization stage, the leader node endeavours to synchronize with other nodes. MTSP is implemented in distributed manner and shows good results for heavy traffic networks.

Power saving management could not be easily achieved without inclusion of some basic aspects like time synchronization, proper coordination of nodes in the mobile ad hoc networks. Yu-Chee Tseng et al. (2002) have proposed the IEEE 802.11 based power management protocols, such as dominating-awake-interval, periodically-fully-awake- interval, and quorum based protocols. These protocols are directly applied for power management. Extensive simulation results are presented to verify the effectiveness of the proposed protocols.

Hyewon et al. (2007) have proposed an energy saving protocol involving ferry nodes. Due to heavy traffic deployment in mobile ad hoc networks, delay mechanism draws much attention for regulating traffic. Message ferrying mechanism is such a mechanism advocated for adoption while at delay in data delivery and it is most preferable at partitioned network. However nodes can save energy by disabling their radios when ferries are far away. This mechanism is compared with multi-hop routing protocol and simulation studies show that the proposed protocol performs better in energy saving than multi-hop routing protocols.
Energy Saving Dynamic Source Routing (ESDSR) protocol is introduced by Tarique et al. (2005) to maximize the life-span of a mobile ad hoc network (MANET). The ESDSR protocol is the enhancement of DSR protocol but additionally expected life of each node is calculated in order to utilize the power supply properly. As in DSR, it also involves two phases namely Route Discovery and Route Maintenance. Here, the nodes with low battery power are eliminated in the first phase. Once the path is established, each node records its transmitting power to the data packet and sends it to the next hop. Finally, when the destination node receives the data packet, it reads the transmit power of each hop and compares it with the minimum power value. For each node, a power table is maintained and is indicated to the source node via ACK packet. If the required power value is not obtained alternative nodes are selected for packet delivery.

An improved Power Saving Ant Algorithm (PSAA) is proposed by Sun Li-Shan & Zhang (2005) to prolong the ad hoc networks lifetime. PSAA mainly concentrates on the remaining battery power and its variance. The variance of the remaining battery power gives the power consumption equilibrium of the whole network. It works well even when there are changes in network topology. Here, the number of nodes is varied between 10 and 100 in which the expected remarkable performance is achieved when there 40 nodes. Since all the network power is dependent on the batteries, the saving of the battery power is a necessary aspect. By using this power saving Ant algorithm, the battery power could be saved to a greater extent. The prolonging the lifetime is achieved by 45% greater than all other.

Calcev et al. (2007) have proposed a Power Saving Mode (PSM) feature for nodes in ad-hoc networks. Considering an IBSS network, beacon frames are broadcasted that announces the beacon interval Target Beacon Transmission Time (TBTT). At every TBTT, nodes start to compete for
sending beacon packets that are ready to remain awake for the complete duration of Announcement Traffic Indication Message (ATIM) window. In this ATIM window, beacon interval is fixed and frame transmission takes place. Once the receiver receives beacons from the nodes, it waits for the ATIM packets to be received. These packets are either transmitted by unicast or by broadcast methods. Data frames are then transmitted to the receiver. The nodes which do not send any beacon packets, moves to the low power doze mode until current ATIM window expires.

Wang (2010) has developed an energy management model, to maximize the network lifetime. Energy efficient MANET routing protocols ensure that all nodes equally deplete their power level and that efficient routing paths are selected to avoid low energy nodes. The effective use of battery energy of a node has been determined for the communication activities of a network. In this methodology dynamic turning off network interface has been used. Here the mobile nodes have been transferred to sleep mode, when these nodes have no data to transmit or receive in order to save energy. The energy management model is proposed to characterize the various operations in the MAC layer. It consists of two modes: active mode and power saving mode. In this function, time is divided into beacon intervals for energy saving. The routing discovery is determined by means of dynamic routing, where the transmission occurs between the intermediate nodes. The protocols under this approach reduce the energy consumption of nodes and extend the lifespan of network.

Lan Wang & Stephan Olariu (2004) have proposed a novel hybrid routing protocol to decouple the protocol’s ability to adapt to traffic characteristics from its mobility. This protocol minimizes the sum of the proactive and reactive control overhead. This zone routing protocol is hybrid. It adopts pure proactive routing for intra zone traffic and reactive routing for
inter zone traffic. The reactive routing procedure maintained for this protocol is taken through by a mechanism called bordercasting. In this protocol every node maintains two zones: a Crisp Zone and a Fuzzy Zone. First the Crisp zone is maintained by the proactive overhead and it is used to balance the mobility, whereas Fuzzy zone is maintained by means of control overhead. This Fuzzy zone determines the traffic pattern on the routing control overhead. The approach characterizes the traffic pattern and it determines the delay and bandwidth consumption. But these zones do not ensure symmetry in the route discovery and the protocol does not focus on large scale networks.

The energy Efficient Location Aided Routing Protocol (EELAR) which is based on location aided routing (LAR) has been developed by Mohammad (2009). An efficient EELAR protocol enhances the control packet overhead and the delivery ratio is high compared to other protocols. Here the packets are routed efficiently by means of the base station in order to determine the mobile nodes. The strength of the signal is estimated by the distance between the base station and mobile nodes. By keeping the base station as the centre point it is circumstance to a certain area which is subdivided into six equal parts where the coverage area is equal at every mobile node in the six subdivided regions. It has high efficiency in decreasing the overhead and obtaining the location information of the mobile host. This feature may also be used in GPS. Here the routing is done by two folding regions namely the forwarded region and the expected region. This approach is not suitable to all the cases. By increasing the number of areas it maintains a trade-off between control overhead and hence the energy is consumed.

Jiageng Li & David Cordes (2009) have reviewed the power-aware routing protocols in wireless networks. The routing protocol has been classified into two: Activity based and Connectivity based. Activity based protocol addresses the issue of power consumption. This protocol mainly
focuses on power-aware routing decisions and hence it is classified based on different routing procedures, i.e., unicasting, multicasting and broadcasting. Active energy saving protocol involves minimizing the power transmission. Here a routing path is chosen that consumes the minimal amount of energy for the delivery of an individual packet. In passive energy saving protocol, energy is conserved by the sleeping nodes while the network connectivity is maintained by active nodes. This protocol determines the different strategies for on-off schedules of the network nodes. The Geographic Adaptive Fidelity algorithm has been used to determine the sleeping time. In GAF, the ad hoc network is divided into virtual grids. Each grid must keep enough nodes in active state to ensure overall network connectivity, placing other nodes within its grid into a sleeping state to reduce energy consumption.

Sunho Lim & Chita (2009) have proposed an energy efficient protocol called Randomcast Dynamic Source Routing (DSR). It works through overhearing. In this methodology, there is an effective communication random casting mechanism which imposes the specified level of overhearing. A power saving mechanism (PSM) 802.11 is established. It is applied in a MANET with Dynamic Source Routing. This DSR protocol is implemented in order to maintain the node which has data packets and discovered the route. The integration of 802.11 PSM with a DSR routing protocol overcomes the problems caused by random casting. This works by unconditional overhearing which is taken from PSM. The performance is compared by random casting of four schemes in terms of Packet Delivery Ratio (PDR), energy consumption, energy good put and energy balance through simulation.

Wei Liu et al. (2011) has proposed a new scheme namely Device Energy Load Aware Relaying framework (DELAR) which achieves energy conservation in heterogeneous mobile ad hoc networks. DELAR has achieved
the energy conservation by multiple facets, such as power-aware routing, transmission scheduling and power control. A DELAR utilizes the device heterogeneity, nodal residual energy information and nodal load status to save energy in ad hoc networks. Here a hybrid transmission scheduling mechanism is used to schedule and co-ordinate the transmission activities among powerful nodes and normal nodes. The results show that DELAR can significantly reduce the energy consumption and thus it extends the network lifetime.

Gupta & Rao (2011) have introduced Demand Based Energy Efficient Topology (DBET) to reduce energy consumption for low and high network traffic conditions. The method is divided into four phases. In phase-I, the node has been selected based on three factors such as stability factor, utility factor, energy factor. The selected nodes are used for data transmission. In phase-II, the selected node forms a connected backbone in which the remaining node goes to the sleep state and conserves the energy. The active nodes are determined in the remaining phases in which energy consumption can be reduced by choosing a lower energy cost path. DBET uses the only one hop neighbour information.

Jinhua Zhu & Xin Wang (2011) have developed a protocol to reduce the energy consumption based on overhead and mobility. PEER is cost based energy efficient routing protocol. In cost based routing protocol, the total cost of all the links on each available path between the source node and destination node are calculated, and a minimum cost path is selected. There are two mechanism involved in this protocol as path discovery scheme and path maintenance scheme. While comparing normal minimum energy protocols, PEER significantly reduces the routing overhead and path setup delay and it consumes less energy in both static and mobile scenarios.
Preethi & Ramachandran (2011) have proposed an energy efficient route discovery for AODV based on expanding ring search technique. This approach saves energy of the nodes by avoiding the redundant rebroadcasting of the route request packets. Based on the broadcasting of route request, the relaying status of the node is decided. This method reduces the routing overhead during the route discovery process and hence the collision is reduced.

Localized energy conservation algorithm has been proposed by Richa Goyal et al. (2010) for routing in mobile ad hoc networks in order to reduce the energy consumption. This algorithm involves the selection and maintenance of a minimal number of nodes in the network. It consists of two phase coordinator election algorithm. During the first phase the coordinator selects the best set of nodes, in which the selection is done in a distributed and localized manner. In the next phase coordinators are elected to ensure that the coordinators form a connected backbone, in which the coordinators selected in the first phase are disconnected. The algorithm selects a minimum number of coordinators which results in a reduction in energy consumption and hence lifetime of the system is increased.

Chi Ma et al. (2011) have introduced a novel energy model for batteries and their behaviour on routing in wireless ad hoc networks. In this model battery aware scheme has been carried out for routing and it effectively recovers the device’s battery capacity in order to achieve high energy efficiency. The prioritized BAR scheme is also proposed to sure that the end to end routing connections are function well for time sensitive applications. The performance is evaluated in terms of end to end delay and data throughput.

The link stability and energy aware routing protocol in distributed wireless networks determines the link stability and minimum drain rate
energy consumption using a novel strategy. Floriano et al. (2012) have proposed a protocol in which the next hop towards destination is the neighbourhood node that maximizes the joint link stability energy metrics. Here it uses a bi-objective optimization formulation method. The energy needed to send a packet is calculated to enhance the routing strategies. Power dissipation is calculated in terms of both power consumption at transmitter and receiver. Simulations have been carried out in order to evaluate the aspects of data packet delivery ratio, link duration nodes lifetime and average energy consumption.

Srinivas et al. (2010) have reviewed the energy efficiency in static and dynamic ad hoc networks. The power failure of any mobile node reduces the overall network lifetime. The performance of three routing protocols AODV, DSR and WRP for mobile ad hoc networks in static and dynamic scenarios has been compared. The results show that WRP protocol consumes more energy in both static and dynamic ad hoc networks compare to DSR and AODV routing protocols. AODV consumes more energy compared to DSR routing protocol. The energy consumption increases with density in dynamic ad hoc networks but in static ad hoc networks energy consumption decreases with density.

Yonghui Chen et al. (2010) proposed an energy saving routing protocol called ECAODV. It is based on AODV. Energy consumption is achieved by nodes density and effective flooding mechanism. Local flooding mechanism is used to reduce the repeated route discovery process and expenditure on route repair process. The system shows better network performance when compared to the other protocols.

LBE-ARAMA is a novel routing algorithm. It was proposed by Floriano & Mauro (2009). It makes use of Swarm Intelligence concept. It uses minimum MDR path for energy saving and Round Trip Time (RTT) delay for
data traffic balance. It satisfies multiple metrics, such as load balancing, end-to-end delay and energy saving.

Yu-Chee et al. (2002) proposed three power save protocols. The approach involved switching mobile nodes into low power sleep mode. The three power save protocols are dominating-awake-interval, periodically-fully-awake-interval, and quorum-based protocols. MANET has characteristics like unpredictable mobility, multi-hop communication, and without clock synchronization. These three protocols are directly applied to IEEE 802.11 MANETs. Results from extensive studies show better performance.

### Table 3.1 Research Contribution of Existing Energy Aware Protocols

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Author’s name (Year)</th>
<th>Research Work</th>
<th>Contribution/limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emmanouel et al. (2009).</td>
<td>Slow Start Power Controlled Protocol (SSPC)</td>
<td>Reduced energy consumption is achieved by adjusting the node transmission power to the minimum required value</td>
</tr>
<tr>
<td>2</td>
<td>Rui Yang et al. (2010)</td>
<td>Multicast Ad Hoc On-Demand Distance Vector) Routing Protocol</td>
<td>Communication with a minimum of control Packet overhead</td>
</tr>
<tr>
<td>3</td>
<td>Wang Bo et al. (2009)</td>
<td>A Novel Routing Protocol Based On An Energy Model In Ad Hoc Networks</td>
<td>Distribution of energy consumption and minimization of total energy transmission</td>
</tr>
<tr>
<td>4</td>
<td>Savazzi &amp; Spagnolini (2007)</td>
<td>Multihop Cooperative Transmission Chain</td>
<td>MCTC is inherently recursive and the route selection is based on different metrics</td>
</tr>
<tr>
<td>Sl. No</td>
<td>Author’s name (Year)</td>
<td>Research Work</td>
<td>Contribution/limitation</td>
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<tr>
<td>6</td>
<td>Qing Zhao et al. (2007)</td>
<td>Energy-Aware Geo-Location-Aided Routing (EAGER)</td>
<td>Divides the network into different proactive cells based on self-location information</td>
</tr>
<tr>
<td>7</td>
<td>Dhurandher et al. (2008)</td>
<td>Energy-Efficient On-Demand Routing Algorithm</td>
<td>Provides a balanced approach on consuming energy among various nodes in the network</td>
</tr>
<tr>
<td>8</td>
<td>Wu &amp; Tuan (2009)</td>
<td>Power Saving Routing With Power Sieving (PSRPS)</td>
<td>Attempt to save power by dividing the network area into many square grids with the aid of location information</td>
</tr>
<tr>
<td>9</td>
<td>Yi-Chao Wu &amp; Chiu-Ching Tuan (2007)</td>
<td>Energy Saving Cache-Based Routing Protocol (ESCR)</td>
<td>Whole network is divided into grids of side, d.</td>
</tr>
<tr>
<td>10</td>
<td>Neeraj et al. (2011)</td>
<td>Reviewed The Power-Saving Protocols</td>
<td>Basic energy conserving algorithm (beca), adaptive fidelity energy-conserving algorithm (afeca)</td>
</tr>
<tr>
<td>11</td>
<td>Kristensen &amp; Bouvin 2008)</td>
<td>SPAN and BECA/AFECA</td>
<td>Two techniques can dynamically handle switching between ON/OFF states of the nodes</td>
</tr>
<tr>
<td>12</td>
<td>Rajeswari &amp; Venkataramani (2012)</td>
<td>Adaptive energy Conserve Routing Protocol for Mobile Ad Hoc Networks</td>
<td>Modified protocol which reduces the energy consumption by probability for a sleep node</td>
</tr>
<tr>
<td>14</td>
<td>Yuhong Luo et al. (2013)</td>
<td>Energy-efficient DSR Routing Protocol</td>
<td>Energy efficient DSR routing protocol, which emphasizes mobility prediction of the nodes</td>
</tr>
<tr>
<td>15</td>
<td>Said Khelifa &amp; Zoulikha (2010)</td>
<td>Energy Reverse Ad Hoc on Demand Distance Vector Routing (ER-AODV)</td>
<td>It uses two mechanisms viz., multiple route reply and residual energy when at route selection in basic AODV protocol</td>
</tr>
<tr>
<td>16</td>
<td>Sunho Lim &amp; Chita (2009)</td>
<td>Randomcast Dynamic Source Routing (DSR)</td>
<td>Effective communication random casting mechanism which imposes the specified level of overhearing</td>
</tr>
</tbody>
</table>
3.7 SUMMARY

In this chapter, various energy saving techniques and routing protocols are discussed. Accomplishing reduced energy consumptions is the major challenge in ad hoc wireless networks. Various issues related to energy management and the existing energy aware protocols are discussed bringing out their merits and demerits. The forthcoming chapter describes various energy aware protocols to overcome the drawbacks associated the existing protocols.