Energy-Efficient Routing Protocols in Mobile Ad Hoc Networks: A Survey

M. Kokilamani[1]
Ph. D Research scholar, Department of Computer science,Government Arts College, Udumalpet-642126. Tamil Nadu, India.,Email:kokilam.udt@gmail.com

Dr. E. Karthikeyan[2]
Head & Assistant Professor, Department of Computer Science,Government Arts College, Udumalpet-642126. Tamil Nadu, India.Email:e_karthi@yahoo.com

---Abstract---

Most ad hoc mobile devices today operate on batteries. Hence, power consumption becomes an important issue. To maximize the lifetime of mobile ad hoc networks, the power consumption rate of each node must be evenly distributed, and the overall transmission power for each connection request must be minimized. These two objectives cannot be satisfied simultaneously by employing normal routing algorithms proposed in past years. In this paper, different energy based routing protocols have studied to design efficient energy based routing scheme. The main contribution of this paper is to provide an exhaustive survey on the energy-efficient routing protocols for MANETs as well as their classification based on its energy efficiency metrics.

Keywords: **Energy Efficiency, Mobile Ad hoc Networks, Routing Protocols**

---

1. Introduction

Mobile ad hoc mobile network [1] [2] is an autonomous system consisting of mobile hosts that do not rely on the presence of any fixed network infrastructure. Depending on the nodes' geographical positions, their transceiver coverage patterns, transmission power levels, and co-channel interference levels, a network can be formed and unformed on the fly. This ad hoc network topology changes as mobile hosts migrate, "disappear" (failure or depletion of battery capacity), or adjust their transmission and reception characteristics. The main characteristics of mobile ad hoc networks are:

- **Dynamic topology**: Nodes are free to move about arbitrarily. In addition, radio propagation conditions change rapidly over time. Thus, the network topology may change randomly and rapidly over unpredictable times.
- **Bandwidth constraints and variable link capacity**: Wireless links have significantly lower capacity than wired links. Due to the effects of multiple access, multipath fading, noise, and signal interference, the capacity of a wireless link can be degraded over time and the effective throughput may be less than the radio's maximum transmission capacity.
- **Energy constrained nodes**: Mobile nodes rely on batteries for proper operation. Since an ad hoc network consists of several nodes, depletion of batteries in these nodes will have a great influence on overall network performance. Therefore, one of the most important protocol design factors is related to device energy conservation.
- **Multi-hop communications**: Due to signal propagation characteristics of wireless transceivers, ad hoc networks require the support of multi hop communications; that is, mobile nodes that cannot reach the destination node directly will need to relay their messages through other nodes.

From the above mentioned characteristics a major concern in MANET is energy conservation due to the limited lifetime of mobile devices. Energy is a precious resource in MANET. For many multi-hop scenarios, nodes are battery-operated, thus requiring efficient energy management to ensure connectivity across the network. Numerous energy aware routing protocols have been proposed using various techniques such as transmission power adjustment, adaptive sleeping, topology control, multipath routing and directional antennas etc. But most of the methods take into account routing metrics such as delay or hop count. They don't consider about transmission energy cost and remaining battery energy. So energy efficiency is directly connected to network lifetime or network capacity.

The main contribution of this paper is to provide an exhaustive survey on the energy-efficient routing protocols for MANETs as well as their classification based on its energy efficiency into three main categories: Power control metrics, Remaining battery power and multipath routing with reliability. We focus on the techniques these protocols use in order to route messages, taking into consideration the energy they consume and how they achieve to minimize this consumption and extend the lifetime of the network.

Moreover, we discuss the strengths and weaknesses of each protocol providing a comparison among them including some metrics (scalability, mobility, power usage, route metric, periodic message type, robustness) in order for researchers and practitioners to understand the various techniques and thus helping them to select the most appropriate one based on their needs.

2. Energy Efficient Route Selection Policies

Energy efficiency is a critical issue in MANETs [3] [4] [5]. The existing energy-efficient routing protocols often use residual energy, transmission power or link distance as metrics to select an optimal path. In this section, the focus is on energy efficiency in MANETs and the route selection policies with novel metrics in order to increase path survivability of MANETs. The novel metrics result in stable network connectivity and less additional route discovery operations.

The nodes used in a MANET are resource constrained, they have a low processing speed, a low storage capacity and a limited communication bandwidth. Moreover, the network has to operate for long periods of time, but the nodes are battery powered, so the available energy resources limit their overall operation. To minimize energy consumption, most of the device components should be switched off most of the time. Another important characteristic is that nodes have significant processing capabilities in the ensemble, but not individually. Nodes have to organize themselves, administering and managing the network all together, and this is much harder than controlling individual devices.

Furthermore, changes in the physical environment, where a network is deployed, make also nodes experience wide variations in connectivity and thus influencing the networking protocols. The main design goal of MANETs is not only to transmit data from a source to a destination, but also to increase the lifetime of the network. This can be achieved by employing energy efficient routing protocols. Depending on the applications used, different architectures and designs have been applied in MANETs. The performance of a routing protocol depends on the architecture and design of the network, and this is a very important feature of MANETs. However, the operation of the protocol can affect the energy spent for the transmission of the data. There are some terms related to the energy efficiency on MANETs [6] that are used to evaluate the performance of the routing protocols are as follows:

- **Energy per Packet:** This term is referred to the amount of the energy that is spent while sending a packet from a source to a destination.
- **Energy and Reliability**: It refers to the way that a trade off between different application requirements is achieved. In some applications, emergency events may justify an increased energy cost to speed up the reporting of such events to increase the redundancy of the transmission by using several paths.
- **Network Lifetime**: In MANETs, it is important to maximize the network lifetime, which means to increase the network survivability or to prolong the battery lifetime of nodes. Moreover, the lifetime of a node is effectively determined by its battery life. The main drainage of battery is due to transmitting and receiving data among nodes and the processing elements.
- **Average Energy Dissipate:** This metric is related to the network lifetime and shows the average dissipation of energy per node over time in the network as it performs various functions such as transmitting, receiving, sensing and aggregation of data.
- **Low Energy Consumption:** A low energy protocol has to consume less energy than traditional protocols. This means that a protocol that takes into consideration the remaining energy level of the nodes and selects routes that maximize the network's lifetime is considered as low energy protocol.
- **Distance:** The distance between the transmitter and receiver can affect the power that is required to send and receive packets.

The selection of the energy efficient protocols in MANETs is a really critical issue and should be considered in all networks. The main objective of current research in MANET is to design energy-efficient routing protocols that could support various aspects of network operations. So, techniques and protocols that would consider energy efficiency and transmit packets through energy-efficient routing protocols and thus prolonging the lifetime of the network, are required. The potential task of the protocols is not only to find the lowest energy path from a source to a destination, but also to find the most efficient way to extend the network's lifetime. The continuous use of a low energy path frequently leads to energy depletion of the nodes along this path and in the worst it case may lead to network partition.

3. Challenging Factors Affecting the Energy-Efficient Routing Protocols Design Issues:

MANETs, despite their innumerable applications, suffer from several restrictions concerning, mainly limited energy deposits, limited processing power, and limited bandwidth of the wireless links connecting mobile nodes. One of the most significant design goals of MANETs is to go through data communication while trying, at the same time, to contribute to the longevity of the network and to preclude connectivity a basement through the use of aggressive energy management techniques.

The design of energy-efficient routing protocols in MANETs [7] is influenced by many factors. These factors must get over before efficient communication can be achieved in MANETs. Here is a list of the most common factors affecting the routing protocols design:

- *Node Deployment*
- *Node/Link Heterogeneity*
- *Energy Consumption Without Losing Accuracy*
- *Scalability*
- *Network Dynamics*
- *Fault Tolerance*
- *Connectivity*
- *Transmission Media*
- *Quality of Service*

Because of all these disparities, several new routing mechanisms have been developed and proposed to solve the routing problem in MANETs. These routing mechanisms have taken into account the inherent features of MANETs along with the application and architecture requirements. A high efficient routing scheme will offer significant power cost reductions and will improve network longevity. Finding and maintaining routes in MANETs is a major issue since energy constraints and unexpected changes in node status (e.g., inefficiency or failure) give rise to frequent and unforeseen topological alterations. Routing techniques proposed in the literature for MANETs employ some well-known routing tactics, suitable for MANETs, to minimize energy consumption.

4. Energy efficient routing protocols:

In this section the literature survey of energy efficient routing techniques are discussed to extend the lifetime of the network.

MTPR (Minimum Total Transmission Power Routing) [8] finds the path with the minimum power consumption. MTPR considers the SNR (signal to noise ratio) and sets a threshold (BER, Bit Error Rate) in order to select a path in which each link in the selected path satisfies, where SNR is the signal-to-noise ratio; i and j are the sending and the receiving nodes, respectively; Pi is the transmitting power of the sending node; Gi,j is the enhancement of the link between nodes i and j; μ_j is the noise detected by the receiving node; k is a neighbouring node of the receiving node; and β_j is the threshold BER. A sending node can determine the minimum power necessary to transmit packets in order to minimize power consumption. To find the path with the minimum power consumption, MTPR collects all the paths in which each link in a path satisfies SNR and P_l, where Pl is a path in which each link satisfies SNR. Accordingly, MTPR selects from all paths the one path that consumes the minimum power, as shown in $P(r_0)$

$$SNR_j = \frac{P_i G_{ij}}{\sum_{k \neq i} P_k G_{kj} + \mu_j} > \beta_j (BER)$$

$$P_l = \sum_{i=0}^{d-1} P(n_i, n_{i+1}) \ for\ all\ node\ n_i\ \epsilon\ route\ l$$

$$P(r_0) = \min_{l \in r_*} P_l$$

MTPR causes the nodes in the routing path to use less transmission power in order to reduce power consumption. However, the decreased transmission power is significantly related to the threshold; that is, if the threshold is too high, a path in which the links satisfy SNR may not be found. If the threshold is too low, the decreased transmission power may result in poor transmission bandwidth, resulting in increased transmission delay and power. With power control, a receiving node can easily move out of the communication range of a sending node, leading to path breakage because of the mobility of the nodes.

The Minimum Battery Cost Routing (MBCR) [9] takes into account the remaining power of nodes to prolong network lifetime by selecting one path with the maximum remaining power from all available paths. To find the path with the maximum remaining power, MBCR calculates the sum of the remaining power of each node in a path, using Eq. (4) and (5)

$$f_i\,(t) = \frac{1}{C_i(t)}$$

$$B\,(r_d) = \sum_{i=0}^{d} f_i\ (t)$$

$$B(r_0) = \min_{rd \in r*} (B(r_d))$$

where $C_i(t)$ is the remaining power of node *i* at time *t* and $B(r_d)$ is the sum of the inverse of the remaining power of nodes in path d. MBCR uses Eq.(6) to select from set r_* of all paths the path $B(r_o)$ with the maximum remaining power. Although MBCR uses the inverse of the remaining power of the nodes in a path to select the desired path, the selected path may have a node with low remaining power. This may cause path breakage during data transmission.

Vergados et al. proposed xMBCR [10], which is an improved version of MBCR and MMBCR, to have higher network lifetime than MBCR and MMBCR. xMBCR modifies the battery cost function of MBCR, as shown in

$$f_i\,(t) = \left(\frac{1}{C_i(t)}\right)^p$$

where $C_i(t)$ is the remaining power of node *i* at time *t* and *p* is a constant. When *p* is 1, the battery cost function of xMBCR is equal to the one of MBCR. In addition, when *p* is equal to zero, xMBCR can find the shortest routing path. When p grows, the behaviour of xMBCR is more and more similar to MMBCR. When p is approaching to an infinite quantity, xMBCR is almost equal to MMBCR. Therefore, with the adjustment of the p value, xMBCR has higher network lifetime than MBCR and MMBCR.

The Min–Max Battery Capacity Routing (MMBCR) [11] selects the path in which the minimum remaining power of nodes in this path is greater than the maximum remaining power in other paths, using

$$P_{MMBCR} = \min_{R \in S} \left[\max_{n \in R} \frac{1}{BC_n} \right]$$

where *S* is the set of all paths, *R* is a path, and *BCn* is the remaining power of node n. In MMBCR, a routing path that contains a node with low remaining power can be avoided. However, MMBCR does not take transmission power into account.

To solve this problem, Condition Min–Max Battery Capacity Routing (CMMBCR) [12] which considers both the power consumption during data transmission and the remaining power of nodes, was proposed. Taking into account the transmission power and the remaining power, CMMBCR combines MBCR and MMBCR. CMMBCR has a pre-defined threshold for the remaining power of nodes. When the remaining power of a node is greater than the threshold, the MTPR protocol is used to reduce power consumption. However, when the remaining power of nodes is less than the threshold, the MMBCR protocol is used to prevent nodes with low remaining power from becoming a part of the routing path.

The Minimizing the Maximum used Power Routing (MMPR) [13] selects the path that has minimum power consumption for data transmission by finding all the routing paths from a source node to a destination node and calculating the power consumed by each path. In addition, MMPR also takes into account the power consumption of each node to balance the total power consumption, so the result is network lifetime is increased. In the path discovery phase, MMPR computes the power consumption of each node for data transmission to obtain the total power consumption of a routing path using

$$B(r_0)=\min_{rd\in r*}(B(r_d))$$

where $B(r_d)$ is the power consumption of path r_d and r is the set of all paths. With regard to the balance of power consumption of the nodes, MMPR computes the "loading value" of a node by taking into account the remaining power, transmission power, receiving power, overhearing power, and threshold value. If the loading value of a node is larger than that of another node, then the node consumes more power. To balance the power consumption of nodes in a network, a node with a high loading value has a low probability of being a part of the routing path. In MMPR, although the power consumption for data transmission and the balance of power consumption among nodes are taken into account, the result depends on the threshold value. If the threshold is too high, the routing path may be difficult to construct. By contrast, if the threshold is too low, the effect of balancing the power consumption may not be obvious. Channel contentions and transmission bandwidth are not considered in MMPR.

Gomez et al. Proposed [14] the PARO protocol which evaluates the distance between two nodes to determine the transmission power needed to reduce power consumption. In PARO, it is assumed that each node can directly communicate with all the other nodes in the network (a one-hop network). A sending node uses the maximum power to transmit the first packet to the destination node. After the source node transmits the first packet to the destination node and receives the ACK packet successfully, the source node can use d^4 and T_{min} to determine the distance from itself to the destination node, as well as the minimum power needed for data transmission to the destination node. Here d is the distance between the source node i and the destination node j; Ti,j is the power consumed to send a packet from node i to node j; Ri,j is the signal strength of packets that are received by node j and that are sent by node i; Gt and Gr are the antenna gains of the sender and the receiver, respectively; and ht and hr are the antenna heights of the sender and the receiver, respectively. In addition, in T_{min}, for node i, Rmin i is the minimum received power strength of the received packets sent by receiving node j and Tmin i,j is the minimum power needed for transmitting packets from node i to node j.

$$d^4 = \frac{T_{i,j}G_tG_rh_t^2h_r^2}{R_{j,i}}$$

$$T_{i,j}^{min} = \frac{R_i^{min}d^4}{G_tG_rh_t^2h_r^2}$$

In addition, because the network is fully connected, other nodes in the network also receive the data packet sent by the sending node and the ACK packet issued by the receiving node. Therefore, using the above equations a node can determine whether less power is consumed when a source node transmits a data packet through it to the destination node or when a source node transmits a data packet to the destination node directly. If the source node transmitting data via that node consumes less power, the node broadcasts a message to the source and the destination nodes to help with data transmission. After the source and the destination nodes receive the message from the node, the source and the destination nodes can modify the data transmission with the help of the mobile node.

Wang et al., proposes ES-AODV [15] to reduce power consumption, it uses the relationship between the distance and signal strength to determine the minimum power for data transmission. To prevent transmission failure due to signal decay, ES-AODV takes the desired received power strength P0 and divides it by the signal decay ratio to obtain the minimum data transmission power Pmin. Accordingly, to transmit data, ES-AODV selects from all available paths the one path that consumes minimum power, as shown in Eq., where P(i,j) is the power consumed in transmitting data from node i to node j, n is the number of nodes in path l, and P(l,n) is the power consumed in transmitting a packet along path l. When the signal decay ratio (SAR) is taken into account, the power P_ (l,n) consumed in transmitting a packet along a routing path is as shown in Eq.

$$P_{(l,n)} = \sum_{i=1}^{n-1} P_{(i,i+1)}$$

$$P`_{(l,n)} = \sum_{i=1}^{n-1} P_{min} = \sum_{i=1}^{n-1} \frac{P_{(i,i+1)}}{SAR_{(i,i+1)}}$$

In ES-AODV, the power control method is used and the signal decay problem is taken into account to reduce power consumption. However, because of the mobility of the nodes, the transmission path can be easily broken during data transmission.

PAMP (Power-Aware Multi-Path routing protocol) [16] assumes that the source node knows the amount of power consumed in transmitting a unit of data. In the path discovery phase, the remaining power of nodes is recorded in the RREQ packet. The minimum remaining power of nodes in a path is the amount of power available for the path for data transmission. After the destination node receives the first RREQ, it records the amount of power available for a path and computes the amount of data transmitted to determine whether the available amount of power can complete the data transmission. If the available amount of power for the path is not adequate to complete data transmission, the destination node waits for the later RREQs until the amount of power is available for a path that satisfies the data transmission or until all RREQs arrive at the destination. The destination node also records all paths which the received RREQs have taken. After finding the desired path or after receiving all RREQs, the destination node replies by sending the RREPs for all recorded paths to the source node in order to construct multiple paths. During data transmission, if path breakage occurs, PAMP uses another path to continue the data transmission. PAMP constructs multiple paths so that data transmission can continue if path breakage occurs. However, the transmission bandwidth of the alternative paths may decrease, causing more power to be consumed because of the mobility of the nodes.

REAR (Reliable Energy Aware Routing protocol) [17] finds a stable path in order to reduce the number of path breakages. In the path discovery phase, REAR excludes the nodes with low remaining power so that nodes in the found path have enough power to complete data transmission. In addition, REAR also finds another backup path that can continue data transmission if path breakage occurs. With the backup path, the rerouting overhead due to path breakage can be reduced. However, the backup path may be broken or have low transmission bandwidth if it is used to transmit data.

LAMOR (Lifetime-Aware Multipath Optimized Routing) [18] takes into account multimedia data for transmission. To prolong network lifetime, LAMOR uses multiple disjoint paths to transmit data simultaneously in order to prevent the nodes in a routing path from consuming too much power. In LAMOR, the threshold value of the remaining power is used to exclude the nodes with low remaining power from being a part of the path. When the remaining power of a node is less than the threshold, the node goes into sleep mode in order to save power. During the path discovery phase in LAMOR, each node helps to transmit a RREQ once to reduce the overhead for discovering multiple paths. After the destination node receives multiple RREQs, multiple disjoint paths are discovered. LAMOR uses the rate allocation algorithm to distribute mass data flow in multimedia data transmission.

Meng Li, et.al. proposed a protocol Energy-aware Multipath routing Protocol (EMPR) [19] for MANET. In this scheme by sharing information among physical layer, MAC sub-layer and network layer, EMPR efficiently utilized network resources. EMRP calculates weight *(w)* of each node along the path to makes a decision to select that path.

$$W= \sum_{i=1}^{n}(\alpha \times W_{energy}^{i} + \beta \times W_{queue}^{i})$$

EMPR sorts all available routes in an ascending order of W and takes the top N sets of routes as primary paths to transmit data and take next N sets of routes as backup paths. Simultaneously transmitting packets along these routes need extend the lifetime of node and whole network.

Multipath Energy-Efficient Routing Protocol (MEERP) is proposed in [20]. The protocol selects energy-efficient and node disjoint paths based on the residual energy and successful transmission rate. In this protocol only a single path is used at data transmission from the multiple paths. Simulation result of the protocol shown that the protocol increases network lifetime but packet delivery ratio is less.

Omar Smail et al. [21], propose a new algorithm called Ad Hoc On-Demand Multipath Routing with Lifetime Maximization (AOMR-LM), which preserves the residual energy of nodes and balances the consumed energy to increase network lifetime. To define the node energy and average energy path as shown below

$$e_{averageNet}\big(P(u_0,u_n)\big) = \frac{e_{sum\,(P_i(u_o\,,u_n))}}{\sum \overline{P_l(u_0,u_n)}}$$

$$e_{level}^{u_0,u_n}(u_j) = \frac{w(u_j)}{e_{averageNet}(P(u_0,u_n))}$$

Based on the individual nodes energy level the average energy path level is defined to select best path to transfer the data during communication .The authors introduce threshold and co-efficient factors for selecting homogenous paths in terms of energy. However, reliability of the link and transmission energy cost are taken into account for path selection, they minimizes to network partitioning and re-route discovery.

Minimum Transmission Power Consumption Routing protocol (MTPCR) [22], takes into account high transmission bandwidth as a path selection parameter. MTPCR considers power consumption, distance and transmission bandwidth for discovers the desired routing path that has reduced power consumption during data transmission. Also path maintenance mechanism to maintain good path bandwidth and efficiently reduces number of path breakages. Thus, little additional overhead is required for the computation of the transmission bandwidth in the route discovery process.

Localized Energy-Aware Restricted Neighbourhood routing (LEARN) [23], consider critical transmission radius and energy mileage to guarantee energy- efficiency in route selection. This protocol is based on geographical localized routing, so the routing decision only uses local information of distance and energy consumption. Thus, mobility and link cost is taken into account for optimal path selection, this avoids path failures and congestion.

Sungoh kwon et al. [24] presented a novel Energy-efficient Unified Routing (EURo) algorithm that adapts to varying wireless environments. This algorithm takes into account four key wireless system elements such as transmission power, interference, residual energy and energy replenishment in great manner. Based on the above key factors the algorithm calculates weight vector for energy replenishment and link scheduling. The interference level also considered as main factor for classifying the nodes on the path, Hence, this algorithm is capable for large scale networks in terms of topology changes and energy conservation.

Chi Ma and Yuanyuan Yang introduce Battery-Aware Routing Scheme (BAR) [25] and prioritized BAR for wireless ad hoc networks. This scheme implements battery awareness in routing protocols. By dynamically choosing the devices with well-recovered batteries as routes and leaving the fatigue batteries for recover. The BAR scheme can effectively recover the device's battery capacity to achieve higher efficiency. This BAR & PBAR scheme increases network lifetime and data throughput up to 28% and 24% by considering energy consumption and distance, but it could fail to support link reliability and mobility.

Javad Vazifehdan et al. [26] propose two novel energy aware routing algorithms called Reliable Minimum

Energy Cost Routing (RMECR) and Reliable Minimum Energy Routing (RMER). RMECR select paths based on its remaining battery energy, energy consumption and quality of links. RMER finds routes minimizing the total energy required for end-to-end packet traversal. Both schemes considers minute details such as energy consumption of processing elements, Limited number of retransmissions, packet sizes, Link weight , expected energy cost into detail. This reduces delay in finding path and support bandwidth constraints.

Young-Min Kim presented Ant Colony Optimization based Energy Saving Routing (A-ESR) [27] to overcome the energy-consumption minimized network (EMN) problem. The A-ESR scheme introduces the traffic centrality concept to measure traffic volumes along the nodes on the route. Based on the above factor every node on the path determines delay information and chooses lightly-loaded links for transmission. It balances the traffic load efficiency, but fails to support minimizing energy consumption and remaining battery energy.

5. Comparisons of energy efficient routing protocol schemes

This section provides a qualitative and theoretical comparison of above mention energy efficient routing protocols to extend the lifetime of the node in MANETs. The key differences among the routing protocols lie in the method of energy factor estimation and the decision on route selection based on energy cost for transmission, residual battery energy, link reliability and number paths selected for transmission, routing overheads and scalability.

Table-1 : Energy efficient routing protocol comparison:

Routing Protocol Scheme	Route metric	Route Discovered	Scalability	Routing Overhead
MTPR	Signal to noise ratio & Bit error rate is considered	Single	Low	High
MBCR	Nodes with high remaining power is considered	Single	Low	High
xMBCR	Nodes with high remaining power and transmission cost is considered	Single	Low	High
MMBCR	Paths with high remaining battery energy is selected	Single	Limited	High
CMMBCR	Combines MTPR and MMBCR	Single	Limited	High
MMPR	Based on the Load value of the node power consumption is taking into account	Single	Limited	High
PARO	Distance and minimum power strength is considered	Single	Good	High
ES-AODV	Distance and signal strength are considered to determine the minimum power for data transmission	Single	Low	Optimum
PAMP	Transmission energy cost and minimum remaining battery energy cost is considered	Multiple	Limited	High
REAR	Low energy nodes are excluded and provide backup path with less routing overhead	Multiple	Limited	Low
LAMOR	Remaining battery energy with modes of the nodes is considered	Multiple	Good	Low
EMPR	Cross layer optimization and node weight is considered	Multiple	Limited	Optimum
MEERP	Node disjoint paths with residual energy is considered	Multiple	Good	Low
AOMR-LM	Homogenous path selection is made based on link reliability and transmission cost	Multiple	Good	Very Low
MTPCR	Based on distance, high transmission bandwidth with low overhead is taking into account	Multiple	Good	Low
LEARN	Consider critical transmission radius and energy mileage	Multiple	Good	Low
EUR_o	Transmission power, interference, residual energy and energy replenishment is considered	Multiple	Good	Optimum
BAR	Battery capacity and various mode are considered	Multiple	Good	Low
RMECR	Energy cost, Residual energy and link cost is taken into consideration	Multiple	Good	Low
EMN	Transmission cost is calculated based on traffic load and remaining battery energy	Multiple	Good	Low

6. Conclusion

In our days the MANETs have greatly expanded playing an important role for the efficient data communication selection and their delivery. The energy efficiency is a very important issue for the networks especially for MANETs which are characterized by limited battery capabilities. The complexity and reliance of corporate operations on MANETs require the use of energy-efficient

routing techniques and protocols, which will guarantee the network connectivity and routing of information with the less required energy. Therefore, the application of the proper routing protocol will increase the network lifetime and at the same time it will ensure the network connectivity and efficient data delivery. This survey addresses the important key factors to selecting energy efficient routing schemes to prolong the lifetime of the node and network.

Acknowledgement

This work is supported by University Grants Commission (UGC-MRP (F.No:41-614/ (2012) SR) under the Major Research Project Scheme.

References

[1]. S Corson and J Macker, Mobile Ad Hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations, *IETF WG Charter*, http://www.ietf.org/html.charaters/manet-character.html, (1999)

[2]. C Siva Ram Murthy and BS Manoj, AD Hoc Wireless Networks, *Pearson Education*, (2004)

[3]. K. Kar, M. Kodialam, T. Lakshman, and L. Tassiulas, Routing for Network Capacity Maximization in Energy-Constrained Ad-Hoc Networks, *Proceedings of IEEE Computer and Communications (IEEE INFOCOM '03)*,1, pp. 673–681, (2003)

[4]. J.-H. Chang and L. Tassiulas, Energy Conserving Routing in Wireless Ad-Hoc Networks, *In Proceedings of the 19th Annual Joint Conference of the IEEE Computer and Communications(IEEE INFOCOM '00)*, pp. 22–31 , (2000)

[5]. Q. Dong, S. Banerjee, M. Adler, and A. Misra, Minimum Energy Reliable Paths Using Unreliable Wireless Links, *Proceedings of ACM Int'lSymp. Mobile Ad Hoc Networking and Computing (MobiHoc)*, (2005)

[6]. L. Alazzawi, A. Elkateeb, Performance Evaluation of the WSN Routing Protocols Scalability", *Journal of Computer Systems, Networks, and Communications*, 2(14), pp. 1-9, (2008)

[7]. L. Junhai, X. Liu, and Y. Danxia, Research on Multicast Routing Protocols for Mobile ad-hoc Networks, *Computer Networks*, , 5(52), pp. 988-997, (2008)

[8]. Scott, K., and Bambos, N., Routing and channel assignment for low power transmissionin PCS, *In: Proceedings of IEEE ICUPC*, pp.498–502,(1996)

[9]. S. Singh, M. Woo, and C.S. Raghavendra, Power-Aware Routing in Mobile Ad Hoc Networks, *Proc. ACM MobiCom*, pp.181-190, (1998)

[10]. D.J. Vergados, N.A. Pantazis, and D.D. Vergados, Energy- Efficient Route Selection Strategies for Wireless Sensor Networks, *Mobile Networks and Applications*, 13(3-4), pp.285-296 , (2008)

[11]. Toh, C.K., Maximum battery life routing to support ubiquitous mobile computing in wireless ad hoc networks, *IEEE Communication Magazine*, pp. 138-147, (2001)

[12]. Toh, C.K., Performance evaluation of battery-life-aware routing schemes for wireless ad hoc networks, *Proceedings of IEEE International Conference on Communications*, pp. 2824-2829, (2001)

[13]. Kim, K.-R., Min, S.-G., and Yu, N.-K., Maximizing the lifetime of wireless ad hoc networks using minimizing the maximum used power routing , *In Proceedings of 3rd International Symposium on Wireless Pervasive Computing (ISWPC 2008)*,15, pp. 557-561, (2008)

[14]. Gomez, J., Campbell, A., Naghaghuwg, M., and Bisdikian, C., PARO: supporting dynamic power controlled routing in wireless ad hoc networks, *ACM/ Kluwer Journal on Wireless Networks*, 9 (5), pp. 443–460,(2003)

[15]. Wang, X., Liu, Q., and Xu, N., The energy-saving routing protocol based on AODV , *In: Fourth International Conference on Natural Computation*,5, pp. 276-280,(2008)

[16]. Yang, J.S., Kang, K., Cho, Y.-J., Chae, S.Y., " PAMP : power-aware multi-path routing protocol for a wireless ad hoc network", In: Proceedings of IEEE WCNC, pp. 2247-2252, (2008)

[17]. Hassanein, H. and Luo, J.,Reliable energy aware routing in wireless sensor networks, *In: Proceedings of IEEE DSSNS*, pp.54-64, (2006)

[18]. Tan, L., Xie, L., Ko, K.T., Lei, M., and Zukerman, M., LAMOR: Lifetime –aware multipath optimized routing algorithm for video transmission over ad hoc networks, *In: Proceedings of IEEE VTC 2006-Spring*, pp. 623-627,(2006)

[19]. Meng Li, Lin Zhang, Victor O. K. Li, Xium ing Shan and Yong Ren, An Energy-Aware Multipath Routing Protocol for Mobile Ad Hoc Networks, *ACM Sigcomm Asia '05*, pp. 10-12 , (2005)

[20]. SV Gole and SV Mallapur, Multipath energy efficient routing protocol, *International Journal of Research and Reviews in Computer Science (IJRRCS)*,2, pp. 954-958, (2011)

[21]. Omail Smail, Bernard Cousin, Rachida Mekki and Zoulikha Mekkakia, A multipath energy-conserving routing protocol for wireless ad hoc networks lifetime improvement, *EURASIP Journal*

on Wireless Communications and Networking, doi:10.1186/1687-1499-2014-139 ,(2014)

[22]. Ching-Wen Chen and Chuan-Chi Weng, A power efficiency routing and maintenance protocol in wireless multi-hop networking, *The Journal of Systems and Software Elsevier* ,85, pp. 62-76, (2012)

[23]. Yu Wang, Xiang-Yang Li, Wen-Zhan Song, Minsu Huang and Teresa A. Dahiberg, Energy-Efficient Localized Routing in Random Multihop Wireless Networks. *IEEE Transactions on parallel and distributed systems*, 22(8), pp. 1249-1257, (2013)

[24]. Sungoh Kwon and Ness B. Shroff, Energy-Efficient Unified Routing Algorithm for Multo-Hop Wireless Networks, *IEEE Transactions on wireless communications*, 11(11), pp. 3890-3899, (2012)

[25]. Chi Ma and Yuanyuan Yang, A Battery-Aware Scheme for Routing in Wireless Ad Hoc Networks, *IEEE Transactions on vehicular technology*, 60(8), pp.3919-3932, (2011)

[26]. Javad Vazifehdan, R. Venkatesha Prasad and Ignas Niemegeers, Energy-Efficient Reliable Routing Considering Residual Energy in Wireless Ad Hoc Networks, *IEEE Transactions on mobile computing*, 13(2), pp. 434-447, (2014)

[27]. Young-Min Kim, Eun-Jung Lee and Hung-Shik Park, Ant Colony Optimization Based Saving Routing, *IEEE Communications Letters* ,15(7), pp. 779-781, (2011)