Energy Aware Routing Protocols for Mobile Ad hoc Networks

Bhavna Arora*
Dr. (Mrs.) Nipur**

Abstract

A Mobile Ad hoc Network is a dynamic wireless network without any dependence on any kind of infrastructure. The mobile nodes behave both as host and routers. Routing is a critical issue in MANETs as there are frequent route breakage due to node's mobility and power exhaustion. As these nodes have limited battery capacity, energy efficient routing protocols play an important role in keeping up the operational lifetime of the entire networks. This paper presents a survey of various energy aware routing protocols in Mobile ad hoc Networks.

Keywords : Routing, Energy Conservation, Mobile Nodes

1. Introduction

A mobile ad hoc network (MANET) is a network consisting of a set of mobile nodes with no centralized administration. MANET does not rely on any kind of existing wired infrastructure or fixed base station thus is self-configuring, self-organizing and self-maintaining. MANET(s) are easily deployable thus has potential use in a wide variety of disparate situations like moving battlefield communications, disaster – rescue team communications, vehicular traffic management to name a few.

MANET nodes are typically distinguished by their limited power, processing, and memory resources as well as high degree of mobility. The wireless mobile node may dynamically enter or leave the network resulting in frequent topology changes. Due to the limited transmission range of wireless network nodes, multiple hops are usually needed for a node to exchange information with any other node in the network. Thus the nodes behave both host as well as routers for transferring data between any source and destination node. Because the power of nodes is limited designing a power aware or energy efficient routing protocol is an important issue, many such protocols have been proposed so far. This paper provides an overview of some recently proposed energy efficient protocols.

**Assistant Professor, Dept. of Computer Science, Kanya Gurukul Mahavidyalya, Dehradun, India.*
***Associate Professor, Dept. of Computer Science, Kanya Gurukul Mahavidyalya, Dehradun, India.*

2. Routing

Routing protocols for MANETs have been broadly classified as Table –Driven and On- Demand. Table – Driven or Proactive Routing [Murt 96] [Perk 94] protocols are derived from distance – vector and link – state protocols, maintain tables that store routing information. For any change in network topology, they trigger propagation updates through out the network in order to maintain a consistent network view, causing overhead affecting bandwidth usage, throughput as well as power usage. While Reactive routing Protocols [Perk 99] [John 96] are characterized by a path discovery mechanism that is initiated when a source needs to communicate with a destination whose route it does not know. On-demand protocols are more scalable to dynamic, large networks. When a node needs a route to another node, it initiates a route discovery process to find a route. Keeping in mind the energy awareness of the nodes, the reactive protocols are a better choice than the table driven protocols.

3. Energy Aware Routing

The main goal of Power aware routing protocols is to increase the operation life of the entire network and try to delay the time of Network partition. Energy consumption of a node is due to three main factors Transmission of data packet, Receiving a data packet and during Idle time. Energy consumption in transmitting k-bit packet corresponds to Eq. 1 and that of receiving is given as Eq. 2 [Zhen 10]

$$E_{tx}(k,d) = Kd^{-n} X (E_{elec} + E_{amp} X d^{n}) \qquad Eq.\,1$$

$$E_{rx}(k) = k X E_{elec} \qquad Eq.\,2$$

Where d is the distance between two nodes, n is an integer between 2 and 4, E_{amp} is the energy consumption when the inter amplifier transmits a unit and E_{elec} is energy consumption when the inter amplifier transmits a unit. Thus the whole cost of energy for transmitting k bit packet is given by Eq. 3

$$E_{tw}(k,d) = 2Kd X E_{elec} + Kd^{-n} X E_{amp} \qquad Eq.\,3$$

Idle time is the time when a node is not involved in transmission of data packet but remains active in that time. Some protocols suggest such nodes to go into sleep mode for energy consumption. These nodes wake up at intervals for channel listening. But due to the overhead of mode switching and lagged data reception, frequent waking up and sleeping of nodes may result in serious performance degradation and may even increase overall energy consumption in mobile devices. [Kras 02]

Further energy consumption also depends on factors like distance between two nodes, available bandwidth of the link and also the interference of the wireless media. Let P and T be the powers of received and transmitted signals, respectively. Then the relation $P = T/d^{\alpha}$, where d is the distance between the sender and the destination nodes and α is a constant [Stoj 01]. The energy consumption to transmit data packet between distant nodes is more than using an intermediate node if available. However, this route requires more hops but is energy efficient. Thus if $E_{(A,B)}$ is the energy consumed to send a unit data packet from node A to node B which may be at a distance of x from each other, it may be possible that an intermediate node C distance d1 from node A and d_2 from node B has $E_{(A,C,B)}$ which might consume lesser energy even if it require more hops.

The available bandwidth plays an important role in energy consumption, the more the available bandwidth the lesser will be the required energy for the nodes for transmitting data packet. Thus, when choosing a particular route link bandwidth should be taken into account.

Nodes in an ad hoc network communicate through the wireless medium. If a shared channel is used, neighboring nodes must contend for the channel. When the channel is in use by a transmitting node, neighboring nodes hear the transmission and are blocked from receiving from other sources. Furthermore, depending on the link layer protocol, neighboring nodes may have to defer transmission until the channel is free. Even when multiple channels are used, energy consumption may increase due to interference.

4. Energy Aware Metrics

The following are the various energy aware metrics that are used by most of the power efficient routing protocols to either decide on a node's participation in a route or choosing a particular route to transfer data packets.

4.1 **Residual Battery Power** of a Node is the remaining battery power of a node. When using this metric nodes with lesser residual battery are not allowed to participate in route discovery process. Let E_i be initial energy and E_c be the consumed energy of a node, then the remaining energy is denoted by $E_r = E_i - E_c$. The energy remained ratio of node is denoted as $E_p = E_r/E_i$ [Zhen 10].

4.2 **Energy Drain Rate** of a Node represents the rate of energy consumption of a node. Thus we can evaluate the expected lifetime of a particular node, knowing which the traffic can be deviated from the nodes that have high energy drain rate. It is computed by exponential weighted moving average method and gives the estimated energy dissipated per second.[Kim 02]. The cost per packet is calculated as C = RBP/DR where RBP : Remaining battery power and DR : Energy drain rate.

4.3 **Energy consumed/Packet** is the amount of energy consumed to transmit and receive a unit packet. Assuming that some packet j traverses nodes $n_1, n_2, n_3, \ldots n_k$ where n_1 is the source node and n_k is the destination node. Let T(a, b) denote the energy consumed in transmitting and receiving one packet over one hop from a to b [Sing 09]. Then the energy consumed for packet j is given by Eq. 4

$$e_j = \sum (i=1 \text{ to } k-1)\ (n_i, n_{i+1}) \qquad \text{Eq. 4}$$

The goal of this metric is to minimize ej for every packet over a particular route.

4.4 *Time to Network Partition* is that time from the deployment of the mobile ad hoc network at which the network may partition that is some critical nodes (nodes that cause network to partition) may run out of power. In such case the network may partition into isolated networks. But predicting the time of network partitioning is not easy. One of the solution is to identify the critical nodes and avoid making them bottlenecks and using alternate paths for packet transmission. We can identify a critical node by examining its transmission power as weak transmission power of a node results to network partitioning. By using the max flow min cut theorem we can find out a minimal set of nodes that is the cut set, the removal of which will cause the network to partition [Sing 09]. These nodes are identified as critical nodes.

4.5 **Variance in node power levels** minimizing this metric ensures that all nodes in network remain up and running together for as long as possible. Similar to load sharing problem in distributed systems. If all packets of same length, we can achieve equal power drain rate by choosing next hop in round robin fashion.

5. Energy Efficient Routing Protocols

The basic protocols DSDV, AODV and DSR find the shortest paths from source node to destination node, that is the minimum hop routes. However they do not take energy efficiency into account. Two main approaches are used by most energy aware routing protocols:

1. Selecting a path that consumes the least energy to transmit a single packet from source to destination, thus aiming at minimizing the total energy consumption along the path.
2. Intending to protect the overused nodes against breakdown, thus aiming at maximizing the whole network's lifetime.

As the lifetime of MANET depends mainly on each mobile node's battery capacity, thus routing algorithms must provide energy efficient route discovery and route maintenance mechanisms. In this context several energy efficient routing protocols have been proposed:

5.1 Minimum Battery Cost Routing (MBCR) : This protocol is proposed in [Sing 98], it uses the residual battery capacity of a node as a metric for energy efficiency to describe the lifetime of each node. Take a battery cost function which is the inverse of battery capacity.

$f_i(c_i^t) = 1/c_i^t$

Where c_i^t is the battery capacity of node i at time t. The battery cost R_j for route I, consisting of D nodes, is

$$R_j = \sum(i=0, D_j - 1)\, f_i\,(c_i^t)$$

To find the route with the maximum remaining battery capacity, the minimum battery cost route is selected. As the battery capacity decreases the value of cost function will increases. If all nodes have similar battery capacity, it will select shorter hop route. Prevents hosts from being overused, increasing lifetime. But it may be possible that as summation of battery cost is used so routes containing minimum battery capacity may be selected.

5.2 The Min-Max battery Cost Routing (MMBCR) : This protocol is suggested in [Toh 01]. To make sure that no node will be overused, the objective function of MBCR protocol is modified. Instead of summing the battery cost function of all nodes of the individual routes, select the battery cost which is maximum among all nodes of route.

$$R_j = \max\ f_i\,(c_i^t)$$

Where c_i^t is the battery capacity of node i at time t.

Where i is any node contained in Route j. Now select the route with minimum battery cost among all routes. No guarantee that minimum total transmission path will be selected. It can consume more power to transmit user traffic. Thus may reduce lifetime of all nodes.

5.3 Minimum Total Transmission Power Routing (MTPR): This protocol suggested in [Sing 98], focuses on end-to-end energy efficiency. Generally, the route selected by conserving energy is the shortest distance path or minimum hop path. Even though some nodes may be dissipating more energy due to dynamics of link characteristics such as distance or error rate, the end-to-end shortest path naturally leads to conservation of energy in transmission.

Successfully delivering packets from node n_i to n_j requires the Signal-to-Noise Ratio (SNR) at the receiver n_j to be greater than a predetermined threshold ψ_j that is closely related to the Bit Error Rate (BER). Selecting a routing path with minimum total transmission power, achieves minimization of the power consumed per packet, intending to entertain more packets before the network runs into depletion. The transmission power $P_{(ni,\, nj)}$ between nodes n_i and n_j are used as the metric to find a route.

Calculates the total transmission power for all routes between source and destination and selects the route with minimum total transmission power among all routes. Thus MTPR is dependent on, interference noise, distance between nodes, and desired BER. However, this will select route with more hops than other routing algorithm and increases end-to-end delay. This approach does not reflect directly on the lifetime of each node. If the selected routes are via specific nodes, the battery of these nodes will exhaust quickly.

5.4 Conditional Minimum Maximum Battery Cost Routing (CMMBCR) : This protocol is hybrid of both MTPR and MMBCR, is proposed in [Toh 01]. Both goals (maximize lifetime of each node and use the battery fairly) cannot be achieved simultaneously by any of previous schemes. A threshold ϴ is defined which has a value between 0 and 100. If the battery capacity of a node is more than this threshold then MTPR approach is used otherwise CMMBCR is employed.

$$Rj = \Theta \text{ for any route } j$$

Then the desired route is the one that has the minimum battery cost among all routes. Thus we can say that CMMBCR chooses the shortest path if all nodes in all possible routes have sufficient battery capacity but if the battery capacity of some nodes goes below the threshold value then the routes going through these nodes will be avoided resulting in the delay of node's power down.

5.5 Maximum Residual Packet capacity Battery cost Routing (MRPC) : This protocol suggested in [Misr 02], not only identifies the residual battery capacity of a node but also the expected energy spent in reliably forwarding a packet over a specific link. Here the nodes can adjust their transmission power dynamically that is based on the distance between the nodes also it incorporates the effect of link layer error rates and consequent packet re-transmissions. The node-link metric is calculated as

$$C_{i,j} = B_i / E_{i,j}$$

where B_i is residual battery capacity at node i, $E_{i,j}$ is the transmission energy required by node I to transmit a packet over link (i, j) to node j. Thus, the "maximum lifetime" associated with route P is

$$Life_P = \min\{\, C_{i,j} \,\} \text{ where } i, j \text{ belong to } P$$

Thus this protocol not only keeps in mind the node specific power metrics but also link related parameters, to increase the lifetime of the network.

5.6 Conditional Maximum Residual Packet Capacity Battery Cost Routing (CMRPC) : This conditional version of MRPC also presented in [Misr 02], uses the min energy algorithm as long as LifeP associated with the chosen route P lies above a specified threshold; once the critical link-node cost function falls below this value, the algorithm switches to MRPC-based routes. The threshold F is a parameter of the CMRPC algorithm– a lower value of F implies a smaller protection margin for nodes nearing battery power exhaustion. Accordingly, the performance of the CMRPC algorithm will be a function of F. the CMRPC differs from CMMBCR in that the cost functions at all times include the link – specific parameters.

5.7 Power Aware Source routing (PSR) : This protocol proposed in [Male 02] is a source initiated routing protocol that aims to extend the network lifetime of MANET. It finds a route π at route discovery time t such that the following cost function is minimized

$$C(\pi,t) = \sum_{i \text{ belongs to } \pi} C_i(t)$$

Where,

$$C_i(t) = \rho_i \{F_i / R_i(t)\}^{\alpha}$$

ρ is transmit power of node i, F_i is full charge battery capacity of node i and R_i is remaining battery capacity of node i. α, a positive weighing factor is defined as a function of the ratio of the remaining battery capacity over the full-charge battery capacity. As this ratio decreases and becomes less than a specified set of threshold values, α increases according to a fixed schedule. In this way, nodes with very low battery capacity contribute a much higher value to the total path cost. In other words, if a path from source to destination has some nodes with a very low residual battery, the cost of the path will be very high, and therefore, PSR will behave similar to the Max-Min battery cost routing. PSR increases the network lifetime. A greedy policy was applied to fetched paths from the cache to make sure no path would be overused and also make sure that each selected path has minimum battery cost among all possible path between two nodes.

5.8 Energy saving dynamic Source routing (ESDSR): In this protocol as suggested in [Kim 03], the energy level and the transmission power level node are taken into account while finding routes. The source node finds the route R(t) at time t such that the following cost function is maximized

$$C(R,t) = max(R_j(t)) \text{ where}$$

$$R_j(t) = min\{E_i / P_{ti}\}$$

Here R_j is the minimum energy to transmit power ratio for the path j, E_i is the remaining battery of the node i on the discovered path and P_{ti} is the transit power of node i on the discovered path. $R_j(t)$ is also called "minimum expected life". The expected lifetime of is computed at the time of Route Reply using E_i / P_{ti}. It replaces the value recorded in the route reply if the calculated value is less than the recorded value. It repeats the same process for other route reply from other routes. Then the source chooses the path with 'minimum expected life', instead of selecting the shortest path. The transmit power is adjusted link by link which has a major advantage over fixed transmit power. This protocol does not consider the rate of depletion of the node and the minimum power required to send the packet at each node to form a route. Further, there may be longer end to end delay as minimum hop path is not chosen.

5.9 Energy Aware AODV routing (EAODV): This protocol suggested in [Jian 09] is a energy aware modification of Ad hoc on-demand Distance Vector Routing protocol. It selects routes according to the dynamic priority weight and takes hop count as optimization condtion, also a back up routing mechanism is adopted. In EAODV, the route which spends less energy and owns larger capacity is selected. Assuming that routei = n_s, n_1, n_2, … , nd where ns is the source node and nd is the destination node. $R_i(t)$ represents the residual battery energy of node n_i at time t, $C_i(t)$ denote the consumed energy of the node n_i at time t. Then the dynamic priority weight, which represents the link priority is given by

$$\beta_i(t) > \{ R_i(t) / C_i(t) \}^2$$

The square of $R_i(t)$ / $C_i(t)$ prefers selecting a large – capacity and less energy cost routing. The optimal route R_O is bound to $R_O >$ max β_i for any routei that belongs to the set of all possible routes. EAODV also adopts backup routing by searching two routes for the destination during route discovery.

5.10 Minimum energy Dynamic Source Routing (MEDSR): This protocol is suggested in [Tari 07] and has modified the basic Dynamic Source Routing (DSR) protocol. MEDSR works in two phases – route discovery and link by link power adjustment. Two power levels are used during route discovery phase of the protocol. At first, a source node initiates the route discovery to find a route to its destination by broadcasting a route request packet at low power level. If a route is not discovered by the source node at the low power level even after initiating the route request for three consecutive times, then it assumes that the destination is not reachable at low level power. Then a new route request packet is initiated at a high power level. Once a route is discovered by any of the power levels then the link by link transmit power adjustment is done to save even more energy, which is accomplished by the network layer route reply packet.

One limitation of MEDSR is that the data packets travel larger number of hops causing a increase in the per packet delay. Further, residual battery capacity of the nodes is not considered during route discovery.

5.11 Energy Efficient Location Aided Routing (EELAR): The protocol is proposed in [Mikk 09] relies on a base station and the entire network's circular area centered around the base station is divided into six equal sub-areas. The Base station BS stores the location of the mobile nodes in the position table. The Position table is built by the BS by broadcasting small BEACON packets to all the nodes in the network. Based on the position of a node it belongs to one of the six sub areas, nodes send all the route request for a particular destination first to the BS. As the BS is aware of the location of all the nodes so if the destination node belongs to the same sub area as that of the source, then it conveys to the source node that the communication is within the sub area of the source node and not through BS.

Otherwise if Source node and the destination node belong to different sub areas then BS sends a control packet to the source node that the data flow will be through BS. The main aim of this protocol is to reduce the control overhead thus the energy consumption of the nodes is reduced through limiting the area of discovering a new route to a smaller zone. Here a main question arises that how to decide on the number of sub areas into which the entire network should be divided. The optimal number of sub areas depends on the nodes mobility patterns.

5.12 Energy based local maintenance routing (EBLM): This protocol is suggested in [Zhen 10], where the route discovery mechanism is adopted according to the different levels of a node's remaining battery. This hybrid routing protocol considers power conservation and also protects the nodes with scarce battery. During route maintenance remaining energy awareness and warning strategy is also adopted. EBLM uses the ratio of the remaining energy capacity as the cost metrics. In different levels of remaining battery capacity of a node, different energy related routing metrics are applied. Here the whole energy of a node is divided into three levels by using two thresholds. The energy consumption of node I with transmission of k bit packet and receiving m bit packet is shown as

$$E_{wi} = E_{tx}(k,d) + E_{tx}(m)$$

The time when E_{wi} equals to E_i is defined as the lifetime of the node i and is denoted by T_i. Thus the network's lifetime is

$$T_{net} = min_{i\, belongs\, to\, N}\, T_i$$

The main aim of this protocol is to increase the lifetime of the network. Two thresholds r_1 and r_2 are set that divides the energy into three levels. Based on the energy level of a node, it is allowed to take part in the route discovery mechanism. If If $E_r > r_1$, namely energy of each node is abundant, the path with the maximum E_{cw} is preferred as the rule for the source node choosing the route for packets transferring. If $r_1 > E_r > r_2$, namely there are some nodes that consumed much energy, the path with the minimum remaining energy is chosen as the optimization. If $r_2 > E_r$, the path is protected for use. Thus this protocol keeps track of the network from the time of deployment and delays network partitioning and over usage of low energy nodes.

5.13 Cost based Power Aware cross layer AODV (CPCAL – AODV) : This cross layer routing protocol is proposed in [Pati 08] uses Battery capacity of a node as a metric. This approach is based on intermediate nodes calculating cost based on Battery capacity .The intermediate node judges its ability to forward the RREQ packets or drop it. That is it integrates the routing decision of network layer with battery capacity estimation of the MAC layer. The proposed cross layer design is based on sharing the MAC & physical layer information- transmit power, full charge battery capacity and the remaining battery capacity of node at time t. All nodes except the source & destination calculates their link cost C_i using the following formula

$$C(\pi,t) = \sum_{i\ belongs\ to\ \pi} C_i(t)$$
$$C_i(t) = \rho_i \{F_i/E_i(t)\}^{\alpha}$$

Where ρ_i is the transmit power of node i, F_i is full charge battery capacity of node i, $E_i(t)$ is the remaining battery capacity of node i at time t and α is a +ve weighting factor.

After computing, a node adds it to the path cost $c(\pi,t)$. A node before forwarding the RREQ packet learns about its remaining battery capacity & drops the packets when it has a lower battery level than its threshold value ($E_r <= \Theta$). CPACL-AODV saves the precious lifetime of batteries of low power nodes and other network resources. The low power nodes are identified and rejected in RREQ flooding phase itself and not after facing any RREP transmission failures. When a node has a lower battery level than its threshold value ($R_r <= \Theta$), any request is simply dropped therefore the source will not receive a RREP message even if there exists a route between the source and destination.

5.14 Power Effective Source Routing (PESR) : This protocol is suggested in [Sing 09] reduces the energy consumption of the nodes by routing packets on routes that consumes the minimum amount of energy to get the packets to the destination. PESR adjusts the transmission power according to received signal strength. To decide a proper transmission power better for two nodes A and B, node A will first use the maximum transmission power (Ptxmax) to send a packet to node B. Node B receives this packet with received signal strength Pr and decides the region Pri where i =1 to 5 it belongs. The corresponding transmission power will be used by node A and node B for further communication. The values of P_r1, P_r2,…, P_r5 in are increasing order are the boundary signal strength to each region. The cost metric of PESR is defined as minimized $C(\pi,t) = C_{ij}(t)$, where the $C_{ij}(t)$ is

$$C_{ij}(t) = ((d_{ij})^a (F_j / R_j(t))$$

Where d_{ij} is the distance between two nodes i and j, F_j is the full battery capacity of node j, $R_j(t)$ is the remaining battery capacity of node j and a is a positive weighing factor. PESR overcomes the problems of depleting energy by considering cost and threshold energy and also adjusts the transmission power of nodes. But it selects all neighbor nodes instead of polling select nodes.

6. Conclusion

By studying the above mentioned protocols it can be inferred that energy efficiency of the protocol is not only dependant on the Energy aware metrics but also on the link dynamics of the network. Thus equal importance must be given to Link aware metrics like available bandwidth, channel interference, coupling, to name a few. Most of the protocols do not take into account multiple metrics for energy efficiency, that instead of using a single metric if combination of metrics are used then even more power conservation can be achieved. Further, energy efficiency is closely related to load sharing among the nodes as even distribution of load among the nodes will lead to increase in the network lifetime. A cross layer protocol that can conserve power at different layers of the network can be a promising solution for Energy Conservation for Mobile Ad hoc networks.

7. References

1. *[Jain 09] : Jainglian C., Zhaoxiao Z., Wenli Z., Tingrui P. " Energy-aware AODV Routing for Ad Hoc Networks" IEEE NSWCTC (2009).*
2. *[John 96] : Johnson, D.B., Maltz, D.A."Dynamic Source Routing in Ad Hoc Wireless Networks" Mobile Computing. (1996)*
3. *[Kim 02] : Kim D., Aceves G.L., Cano J.C. " Power- Aware Routing Based on the Energy Drain rate for Mobile Ad hoc Networks" ICCCN (2002).*
4. *[Kim 03] : Kim D., Aceves G.L., Cano J.C., Obraczka K., Manzoni P. " Routing Mechanism for Mobile Ad Hoc Networks Based on Energy Drain Rates" IEEE Trans. On Mobile Computing (2003).*
5. *[Kras 02] : Krashinsky R., Balakrishnan H. " Minimizing Energy for Wireless Web Access with Bounded Slowdown " ACM MOBICOM,(2002).*
6. *[Male 02] : Maleki Morteza, Dantu Karthik, Pedram Massoud "Lifetime Prediction Routing in Mobile Ad Hoc Networks" WCNC (2003).*
7. *[Mikk 09] : Mikki M.A., "Energy Efficient Location Aided Routing Protocol for Wireless MANETs" IJCSIS (2009)*
8. *[Misr 02] : Misra A., Banerjee S. " MRPC : maximizing Network Lifetime for Reliable Routing in Wireless Environments" IEEE WCNC (2002)*
9. *[Murt 96] : Murthy, S., Garcia-Luna-Aceves, J.J "An Efficient Routing Protocol for Wireless Networks" Mobile Networks and Applications, Vol. 1, No. 2 (1996)*
10. *[Pati 08] : Patil R., Dr. Damodaram A. " Cost Based Power Aware Cross Layer Routing Protocol for Manet" IJCSNS (2008)*
11. *[Perk 94] : Perkins, C.E., Bhagwat, P. "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers" ACM SIGCOMM (1994).*
12. *[Perk 99] : Perkins, C.E., Royer, E.M "Ad-hoc On-Demand Distance Vector Routing" 2nd IEEE Workshop on Mobile Computing Systems and Applications (1999)*
13. *[Sing 09] : Singh Ashutosh " Power Effective Source Routing Protocol in Mobile Ad hoc Network" International conference on Computing technology and Development. (2009)*
14. *[Sing 98] : Singh S., Woo M., Raghavenra C.S. "Power Aware Routing in Mobile Ad Hoc Networks" MOBICOM (1998)*
15. *[Stoj 01] : Stojmenovic I., Lin X. " Power – aware Localized Routing in Wireless Networks" IEEE Trans. Parallel and distributed Systems. 12-11 (2001).*
16. *[Tari 07] : Tarique M., Islam R., "Minimum Energy Source Routing Protocol for Mobile ad Hoc Networks" IJCSNS (2007).*
17. *[Toh 01] : Toh C.K. " Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks" IEEE Communication Magazine (2001)*
18. *[Zhen 10] : Zheng Shi, Zhang Pu, Zhang Qin-Yu. "A Routing Protocol Based on Energy Aware in Ad Hoc Networks" Information Technology Journal 9-4 (2010)*