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A Study of Energy Efficient MANET Routing Protocols

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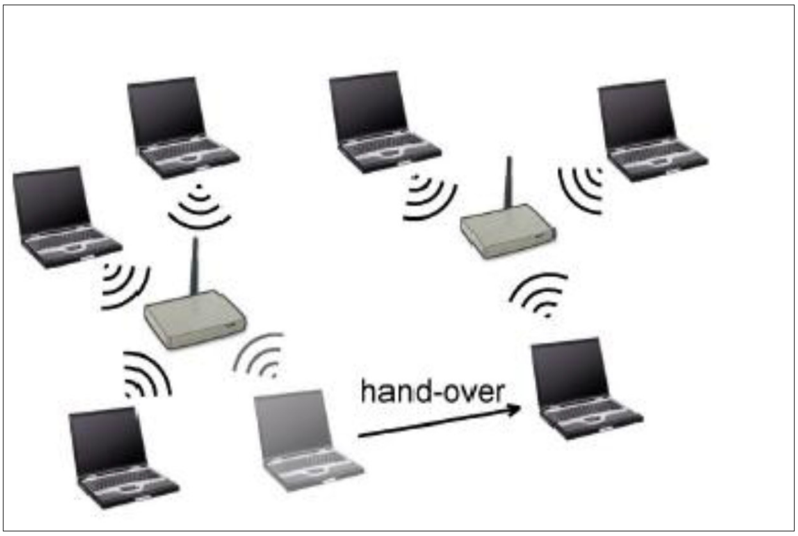
Abstract
In Mobile Ad-hoc Networks (MANET) the contributing nodes have numerous jobs such as router, receiver and sender. Therefore here is a lot of energy consumed by the nodes for the ordinary working of the network since each node has several dissimilar roles. Also in MANET the nodes remain moving continually and this in twist consumes a lot of energy. Since battery capability of these nodes is limited it fails to fulfill the high requirement of energy. The shortage of energy makes the energy maintenance in MANET a significant concern. There is some research carried out on the energy consumption of MANET these days. Some of this research recommends load balancing, sleep mode, transmission power control, etc. We have surveyed so many types of traditional protocols of MANET and their variation which includes energy efficiency.
Keywords: MANET; Multipath Routing; Routing Protocols; Energy Efficiency; Network Life Time

1. Introduction

Over the last few years, the use of mobile devices and mobile networks has grown drastically and with the emergence of low cost wireless networking, a wide range of applications are been incorporated in laptops, mobile phones etc. To enable such availability Mobile Ad-hoc Networks (MANETs) play a vital role, as they provide communication without any fixed infrastructure. In MANET as the scenario is not fixed, nodes rely upon battery capacity of the nodes, which depletes with time. This makes energy a constraint in MANETs, which calls for the need of efficient energy utilization. Hence the studies on Mobile Ad-hoc Networks have also increased recently [1].

There exist three types of mobile wireless networks [2]: infrastructure networks, ad-hoc networks and hybrid networks which combine infrastructure and ad-hoc aspects. An infrastructure network (Figure 1(a)) comprises of wireless mobile nodes and one or more connecting bridges (called as base stations) to connect the wireless network to the wired network. A mobile node within the network looks for the nearest base station (e.g. the one with the best signal strength), connects to it and communicates with it. In this type of network, all communication takes place between the wireless node and the base station and not between different wireless nodes.



(a) An infrastructure network with two base stations.

(b) A mobile ad-hoc network

Fig 1(a) & (b) Infrastructure and ad-hoc networks

When any mobile node gets out of range of the current base station, a handover to a new base station occurs and that will let the mobile node communicate seamlessly with the new base station. These wireless interfaces also allow the devices to interconnect directly with each other in a decentralized way and self-organize into "Ad Hoc Networks". An ad-hoc network does not have any infrastructure. It is devoid of base stations, routers and centralized administration. Nodes may move randomly and connect dynamically to one another. Thus all nodes act as routers and must be capable of discovering and maintaining routes to every other node in the network and to forward packets accordingly.

Mobile Ad hoc Networks (MANET) is a communication network formed by the union of autonomous aggregation of mobile nodes (computers, mobiles, PDAs etc.) and connecting wireless links [1]. The network is modeled in the form of an arbitrary communication graph. In a MANET, there is no fixed infrastructure (Base Station) and since nodes are free to move, the network topology may dynamically change in an unpredictable manner. MANET is decentralized and self-organizing network where the functions from discovering the network topology to delivering the message are carried out by the nodes themselves; In this network each node acts as a router along with its job as an ordinary device. The organization of Ad hoc networks is peer-to-peer multi hop and information packets are relayed in a store-and-forward mode from a source to any arbitrary destination via intermediate nodes. As the nodes are mobile, any change in network topology must be communicated to other nodes so that the topology information can be updated or eliminated. It is not possible for all mobile nodes to be within the range of each other. However, all the nodes are close by within radio range.

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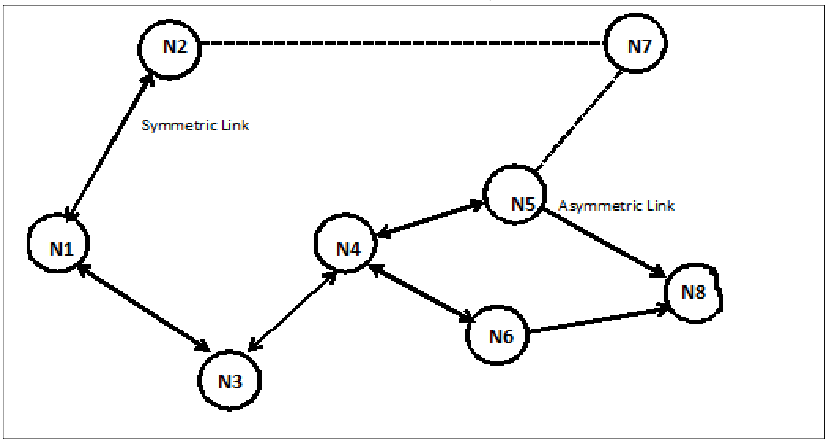

Fig 2 Mobile Ad Hoc Network Topology

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Routing with energy considerations in wireless ad-hoc networks is of immediate present interest due to the advances in the field of wireless computing. Nodes in wireless ad-hoc networks are powered by a portable power source, thus their energy is limited and should be rationed as wisely as possible. The research community has come up with many different ways to approach this problem, and the three most dominating techniques are energy aware packet forwarding schemes, topology control and sleep-mode control. Energy aware packet forwarding techniques focus on trying to forward packets while using the nodes' battery resources in an economical way. Topology control concentrates on finding globally (network-wide) energy efficient settings for signaling ranges for the nodes' radio devices and thereby saving energy in the network. Finally sleep mode control methods economizes energy by putting nodes to sleep whenever possible while trying to maintain routing capacity. Of course, there also exist approaches that combine several techniques.

Rest of the paper is organized as follow: in section 2 we explained characteristics of MANET, section 3 describes the routing protocols of MANET, in section 4 we show the energy efficient routing protocols of MANET, Literature survey of energy efficient routing protocols of MANET is explained in section 5, in section 6 we explained problem statement, future research directions is described in section 7 and finally in section 8 we conclude our paper.

2. Characteristics of MANET

MANET is characterized by some specific features as follows [3]:

1. **Wireless:** The nodes are connected by wireless links and the communication among nodes is wirelessly.
2. **Ad hoc based:** A MANET is a need based network formed by the union of nodes and the connecting links in an arbitrary fashion. The network is temporary and dynamic.
3. **Autonomous and infrastructure less:** Network is self-organizing and is independent of any fixed infrastructure or centralized control. The operation mode of each node is distributed peer-to-peer capable of acting as an independent router as well as generating independent data.
4. **Multi hop Routing:** There is no dedicated router and every node acts as a router to pass packets to other nodes.
5. **Dynamic Topologies:** Due to arbitrary movement of nodes at varying speed, the topology of network may change unpredictably and randomly.
6. **Energy Constraint:** Energy conservation becomes the major design issue as nodes in the MANET rely on batteries or some other exhaustible source of energy.
7. **Limited Bandwidth:** Infrastructure less networks have lower capacity as well as less throughput than the infrastructure based network.
8. **Security Threats:** There are higher chances of physical security threats like eavesdropping, spoofing and denial of service (DoS) in wireless networks as compared to wired networks.

3. Routing in MANET

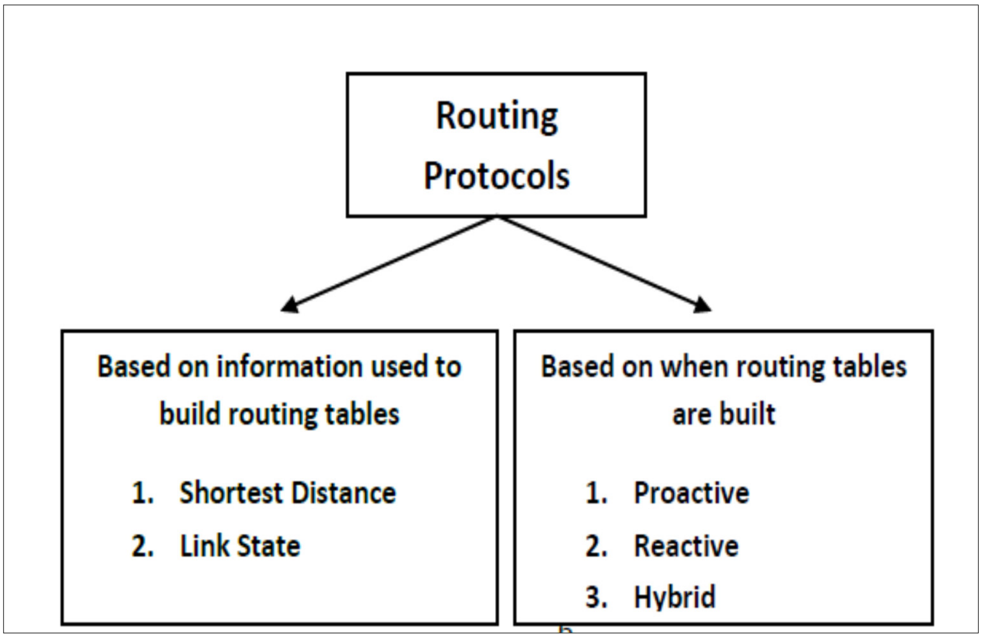
Routing is the process of choosing a path in a network for moving packets form source to destination. It basically involves two processes like finding an optimal routing path and transfers the packets in the internetwork [4]. Routing information of a node is maintained in a routing table. The routing table contains only partial information about possible destinations. For the unknown destinations, these are forwarded to the default router. However the potential problem to this mechanism is some destinations might be unreachable. A routing protocol is the software or hardware implementation of a routing algorithm. A routing protocol uses metrics to select a path to transmit a packet across an internetwork. The metrics used by routing protocols include:

- Number of network layer devices along the path (hop count)
- Bandwidth
- Delay
- Load
- Maximum Transmission Unit (MTU)
- Cost (in terms of Energy Consumption and Time)

Routing protocols are broadly categorized on two bases: based on what information is used to build the routing table and based on when the routing tables are built.

3.1. Based on the information used to build routing tables:

a. **Shortest distance algorithms:** algorithms that use distance information to build routing tables.
b. **Link state algorithms:** algorithms that use connectivity information to build a topology graph that is used to build routing tables.



3.2. Based on when routing tables are built:

A. Proactive algorithms:

Even if not needed, routes to destinations are maintained. Proactive routing protocols, also called (routing) table driven, seek to maintain routing tables at every node containing up to date routing information to all the other nodes in the network. Routing information updates to reflect changes in the network topology are propagated throughout the network, which entails a good deal of overhead. On the other hand, when a message needs to be sent from one node to another node, the response time (for routing at least) of the sending node is very short for actually sending the message, since the route is readily available to the node.

B. Reactive algorithms:

Routes to destinations are maintained only when they are needed. Reactive protocols, which are also called demand-driven protocols, do not seek to maintain a full view of the topology of the entire network at every node. Instead, the necessary routing information is obtained when the sending node needs it, with the cooperation of other nodes. This information is kept for some time and then discarded. This process of getting routing information is known as route discovery. Since the topology of the network can change as node sends information to another node, a route maintenance procedure is also required when topological changes occur.

C. Hybrid algorithms:

For nearby nodes, routes are maintained even if they are not needed and for far away nodes routes maintained only when needed. Hybrid protocols attempt to combine the best features of proactive and reactive protocols. For each node, a table driven approach is applied within a given zone around the node, and a demand-driven approach is then applied outside of that zone.

Proactive Protocols:

1. APRL (Any Path Routing without Loops)
2. CGSR (Cluster-Head Gateway Switch)
3. DSDV (Destination Sequenced Distance-Vector)
4. FSR (Fisheye State Routing, commonly referred to as Fish eye)
5. GSR (Global State Routing)
6. HSR (Hierarchical State Routing)
7. OLSR (Optimized Link State Routing)
8. WRP (Wireless Routing Protocol)

Reactive Protocols:

1. ABR (Associativity-Based Routing)
2. AODV (Ad Hoc On-Demand Distance-Vector Routing)
3. DSR (Dynamic Source Routing)
4. FORP (Flow-Oriented Routing Protocol)
5. LAR (Location Aided Routing)
6. ODMRP (On-Demand Multicast Routing Protocol)
7. PAOD (Power-Aware On-Demand

8. PLBR (Preferred Link-Based Routing)
9. RDMAR (Relative Distance Micro-discovery Ad-hoc Routing)
10. GRAd (Gradient Routing in Ad-hoc networks)
11. SSA (Signal-Stability Based Adaptive)
12. TORA (Temporarily Ordered Routing Algorithm)

Hybrid Protocols:

1. CEDAR (Core Extraction Distributed Ad Hoc Routing)
2. IZR (Independent Zone Routing)
3. STARA (System and Traffic dependent Adaptive Routing Algorithm)
4. ZHLS (Zone-Based Hierarchical Link State)
5. ZRP (Zone Routing Protocol)

4. Energy Efficient Routing

An ideal network is the one that can function as long as possible. On the other hand, optimal routing requires future knowledge and thus, it is not practically viable to have optimized routing in energy constrained environment. Therefore, instead of having energy optimal scheme, we have a statistically optimal energy efficient scheme that considers only past and present and not future knowledge. In order to avoid coverage gap in many surveillance / monitoring applications, lifetime of network is defined. Instead of average time or overall scenarios, the worst case (when a first node dies out) is maximized [5].

Establishing correct and energy efficient routes, in mobile ad hoc networks, is not only an important design issue but also a challenging task. It is because operation time of mobile nodes is the most critical limiting factor. Mobile nodes derive their power from batteries with limited capacity. Power failure of a mobile node affects the node as well as its ability to propagate packets on behalf of others and therefore the overall network lifetime is affected.

Energy efficient routing aims to minimize the energy required to transmit or receive packets i.e., active communication energy. It also tries to minimize the energy consumed when a mobile node stays idle but listens to the wireless medium for any possible communication requests from other nodes i.e., inactive energy. Transmission power control approach and load distribution approach minimizes active communication energy and sleep/power-down mode approach minimizes inactive energy. Each protocol has definite advantages/disadvantages and is well-suited for certain situations and it is not clear any particular algorithm or a class of algorithms is the best for all scenarios.

Many researches are being carried out to develop energy aware routing protocols. New energy efficient routing algorithms are proposed and designed to enhance the network survivability. This is achieved by maintaining the network connectivity to lead to a longer battery life of the terminals. In contrast to AODV which optimizes routing for lowest delay, the energy efficient protocols ensure the survivability of the network which is to ensure that all nodes equally deplete their battery power.

5. Related Work

The energy efficient routing protocols can be classified into three types [6]. The classification is based on the energy consumption, which can be either the active communication energy required to transmit and receive packets or the inactive energy consumed when a mobile node stays idle but listens to the medium. Transmission 45 power control approach and load distribution approach belong to the former category while the sleep/power down mode approach belongs to the latter category.

5.1 Transmission Power Control Approach: In the transmission power control approach, the active communication energy can be reduced by adjusting the node's power just enough to reach the receiving node, but not more than that. The protocols using this approach determine the optimal routing path that minimizes the total transmission energy required to deliver data packets to the destination. The protocols that use this approach include Flow Augmentation Routing (FAR) [7], Online Min-Max Routing (OMM) [8], Maximum Transmission Power Routing (MTPR) [9], and Distributed Power Control (DPC) [10].

i. Flow Augmentation Routing (FAR) [7] protocol can be applied to either static networks or to the networks whose topology changes slowly. In FAR, at all iteration, each origin node $o \in O(c)$ of commodity c calculates the shortest path to each of its destination nodes in D(c). Then the flow is augmented by an amount equal to λ times the actual amount. After the flow augmentation, the shortest cost paths are recalculated and the procedure is repeated until one of the nodes runs out of its initial battery energy. By doing this, we can obtain the flow which will be used at each node to properly split the incoming traffic.
ii. Online Max-Min Routing Protocol (OMM) [8] is applicable to the sparsely deployed networks. This protocol focuses on maximizing the lifetime of the network. The lifetime of the network can be taken as the time to the expiration of the first node. This protocol tries to optimize power consumption by selecting

the path that minimum power consumption and the path that maximizes the minimal residual power of the nodes in the network. The algorithm tries to relax the minimal power consumption for the message to be z Pmin with parameter $z \geq 1$ to restrict the power consumption for sending one message to z Pmin. This algorithm consumes at most z Pmin while maximizing the minimal residual power fraction.

iii. Maximum Transmission Power Routing (MTPR) [9] protocol minimizes the total transmission power consumed per packet and is not concerned with the remaining battery 47 power of the nodes. The transmission power needed to send a packet from source to destination is directly proportional to the distance between the source and the destination. So, transmitting a packet to a node that is farther is consumes more energy compared to the transmission to a node that is nearer. Thus, in order to minimize the transmission power this protocol prefers routes with more number of hops than those with less number of hops. This increases the end-to-end delay in transmitting packet, but reduces the minimum transmission power to send the packet.

iv. Distributed Power Control (DPC) [10],in this protocol the sender uses an appropriate power level to transmit its packets by reducing channel interference and energy consumption, and the final path is selected by minimizing the overall power spent in the end-to-end transmission. This is primarily based on selecting a suitable transmit power level, which also reduces the interference. This transmit power is used as the link cost function in the path discovery and selection.

5.2 Load Distribution Approach: the protocols using the load distribution approach try to balance the energy consumption in the network by using less frequently used nodes, instead of shortest paths. The route selected need not be the lowest energy route, but it ensures that the variance among the node energy levels is reduced. Examples include Local Energy Aware Routing (LEAR) [11], Min-Max Battery Capacity Routing (MMBCR) [9], Conditional Max-Min Battery Capacity Routing (CMMBCR) [9], Request Delay Routing Protocol (RDRP) [12], Energy Aware AODV [13], and Location-aided Power-aware Routing Protocol (LAPAR) [34].

i. Min-Max Battery Cost Routing Protocol (MMBCR) [9]: it is similar to DSR except for a few modifications made in order to achieve energy efficiency. MMBCR tries to optimize the overall lifetime of the network, instead of the end-to-end delay. It takes into consideration the remaining battery capacity of the nodes in selecting the path to send packets from a source to a destination.

ii. Local Energy Aware Routing (LEAR) [11]: it is somewhat complicated compared to MMBCR. It uses additional control messages besides the control messages used by the DSR protocol. LEAR tries to optimize the lifetime of the network by considering a node's willingness to forward packets to other nodes. It takes the shortest path among multiple energy rich paths. An intermediate decides whether to forward a route request packet or not depending on its energy level. If its remaining battery level is greater than a threshold value, it forwards the packet. Otherwise, it drops the packet. Even though the concept of threshold is also used in MMBCR, LEAR uses dynamic threshold values whereas MMBCR uses fixed threshold values. LEAR is also a DSR-based protocol. It works on the same grounds as DSR except for the use of additional control messages used to achieve energy efficiency. In LEAR 52 also, when a node has a packet to send to some node and if does not know any route to the destination, the source node initiates a route discovery procedure. But if an intermediate is not energy rich, it will not forward the route request packet. It simply drops the packet. If all the intermediate nodes in all possible paths drop the route request packet, the route request will never reach the destination node, thus blocking the network.

iii. Request Delay Routing Protocol (RDRP) [12]: it is also a DSR-based routing protocol designed to achieve energy balance among the nodes in an ad hoc network. This protocol tries to optimize the network lifetime. At the same time, it also uses the shortest path among all the energy rich paths. The implementation of this protocol is very simple compared to all the other protocols discussed till now. The protocol works similar to DSR except that the intermediate nodes do not process the request immediately. The intermediate node holds the request packet for some duration'd', which is inversely proportional to the remaining battery energy level of the node. Each node maintains a request buffer to keep a record of all requests pending. This table keeps all the information about the request including the source and destination addresses, sequence number.

iv. Conditional Max-Min Battery Capacity Routing (CMMBCR): The Conditional Max-Min Battery Capacity Routing (CMMBCR) [9] considers both the total transmission energy consumption of routes and the remaining power of nodes. The remaining battery capacity of the nodes is compared with a predefined threshold value. If all the nodes in a route have sufficient remaining battery capacity (i.e., above the predefined threshold), the route is considered to be rich. If there is more than one rich path among the available replies, the path with minimum transmission power is chosen. If none of the replies contain a rich path, the path whose critical node has the highest remaining battery capacity among all the critical nodes is chosen. Thus, CMMBCR is a combination of MTPR [9] and MMBCR [9].

v. Energy Aware AODV: Energy Aware AODV [13] uses a two-step approach to conserve energy of the nodes. In the first, the routing protocol tries to route the packets avoiding the nodes with low energy levels. In the second, the radio interfaces of the nodes turned off whenever they needed to be to conserve energy further. The nodes are classified into three zones 58 depending on their remaining battery levels. Normal zone consists of nodes with battery energy levels greater that 20% of their initial energy. Normal zone consists of nodes with battery energy levels greater that 10%-20% of their initial energy. The nodes that have less than 10% of their initial energy are in the Danger zone. The cost of routing packets through the Danger zone is the highest, next comes the cost of routing through the warning zone and the last is the Normal zone. If a node lies in the danger or warning zone and it has a large number of neighbors, the cost of routing packets through that node is directly proportional to the number of neighbors.

vi. Location-Aided Power-Aware Routing Protocol (LAPAR): In Location-Aided Power-Aware Routing Protocol (LAPAR) [14], the forwarding nodes make the routing of data packets based on the location of the neighbors. The forwarding node sends the packets to the neighboring node whose relay region covers the required destination. If the destination node falls into the relay regions of more than one neighbor, the algorithm makes a greedy choice to select the next hop to forward the packet depending on the distance between the source and the forwarding node and the destination node. The decisions are made locally and they depend on the location of the neighbors.

6. Problem Statement

Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. In particular, energy efficient routing may be the most important design criteria for MANETs since mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. For this reason, many research efforts have been devoted to developing energy aware routing protocols. Mobile nodes in MANETs are battery driven. Thus, they suffer from limited energy level problems. Also the nodes in the network are moving if a node moves out of the radio range of the other node, the link between them is broken. Thus, in such an environment there are two major reasons of a link breakage:

1. Node dying of energy exhaustion
2. Node moving out of the radio range of its neighboring node.

7. Scope for Future Research

More and more energy efficient routing protocols for MANET might come in front in the coming future, which might take security, QoS (Quality of Service) with energy efficiency as the major concerns. So far, the routing protocols mainly focused on the methods of routing, but in future a energy efficient, a secured with QoS-aware routing protocol could be worked on. Ensuring these parameters at the same time might be difficult. A very secure routing protocol surely incurs more overhead for routing, which might degrade the QoS level and energy efficiency. So an optimal trade-off among these three parameters could be searched.

Also, further research is needed to identify the best energy efficient routing protocols for multiple environments. These contexts include nodes positioned in three-dimensional space and obstacles, nodes with unequal transmission powers, or networks with unidirectional links. One of the future goals in designing routing algorithms is adding congestion considerations, that is, replacing hop count performance measure by end-to-end delay. Algorithms need to take into account the congestion in neighboring nodes in routing decisions. Finally, the mobility caused loop needs to be further investigated and solutions to be found and incorporated to position based routing schemes.

8. Conclusion

This Survey work summarized that there is not a single MANET protocol which can provide the finest performance in MANET. Achievement of the protocol differs according to the difference in the network constraints, as we identify that in MANET properties constantly differ. Sometimes the mobility of the node of the network is high while sometimes energy of the node is our major worry. So, we will decide the protocol in such a way that which execute finest for that particular type of network. That’s why we have surveyed so many types of traditional protocols of MANET and their variation which includes energy efficiency.

Energy efficiency is one of the major problems in a MANET, particularly in designing a routing protocol. This survey classified conventional and energy efficient routing protocols. In lots of cases, it is difficult to evaluate them straight since each method has a dissimilar objective with dissimilar hypothesis and utilizes dissimilar means to attain the purpose. Our major apprehension is energy efficiency and we have tried to argue approximately all probable approaches of energy efficient protocols.

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