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Survey of Energy Aware On-demand Multipath Routing Protocols in Mobile Ad Hoc Networks

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Abstract: ***With the advance of wireless communication technologies, small-size and high-performance computing and communication devices like commercial laptops and personal digital assistants are increasingly used in daily life. After the success of second generation mobile systems, more interest was started in wireless communications. This interest has led to two types of wireless networks: infrastructure wireless network and infrastructure less wireless network, it is also called Mobile Ad-Hoc Network (MANET). The Mobile Ad Hoc Networks are essentially suitable when infrastructure is not present or difficult or costly to setup or when network setup is to be done quickly within a short period. They are very attractive for tactical communication in the military and rescue missions like earthquake, flood, tsunami, fire and emergency operations. They are also expected to play an important role in the civilian fora such as convention centers, conferences, and electronic classrooms. The nodes in the MANET are typically powered by batteries which have limited energy reservoir. Sometimes it becomes very difficult to recharge or replace the battery of nodes; in such situation energy conservations are essential. The lifetime of the nodes show strong dependence on the lifetime of the batteries. In the MANET nodes depend on each other to relay packets. The loss of some nodes may cause significant topological changes, undermine the network operation, and affect the lifetime of the network. Hence the energy consumption becomes an important issue in MANET. The main aim of this article surveys many all most all different types of energy aware on-demand multipath routing protocols in the MANET. The previous articles surveyed only few on-demand energy aware multipath routing protocols in the MANET. Hence this article is very useful to research community of MANET.***

Keywords: MANET, Multipath, Energy, Routing, on-demand.

I. INTRODUCTION TO MOBILE AD HOC NETWORKS

Today, we see two kinds of wireless networks but the difference between them is not as obvious as it seems **[2].** The first kind and most used today is a wireless network built on top of a "wired" network and thus creates a reliable infrastructure wireless network. The wireless nodes are able to act as bridges in a wired network is shown in fig.1. This kind of wireless nodes are called base-stations. An example of this wireless network is the cellular-phone networks where a phone connects to the base-station with the best signal quality. When the phone moves out of range of a base-station, it does a "hand-off" and switches to a new base-station within reach. The "hand-off" should be fast enough to be seamless for the user of the network. The second approach, called Ad hoc, does not rely on any stationary infrastructure. All nodes in ad hoc networks are mobile and can be connected dynamically in an arbitrary manner. Each node in such networks behaves as a router and takes part in discovery and maintenance of routes to other nodes. In the MANET every node can perform the role of host as well as router, thus nodes, which are out of transmission range, can be accessed by routing through the intermediate nodes. The network topology of MANET is always changing, as their mobile nodes are free to move around and can freely leave or join the networks shown in fig 2.

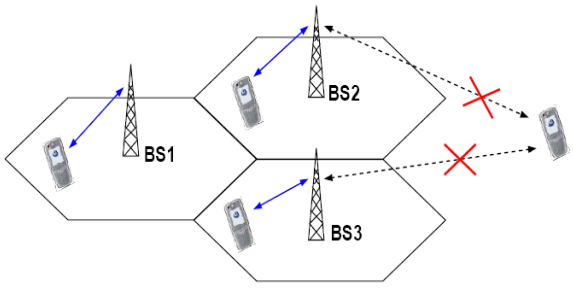

Fig.1. Illustration of the infrastructure network

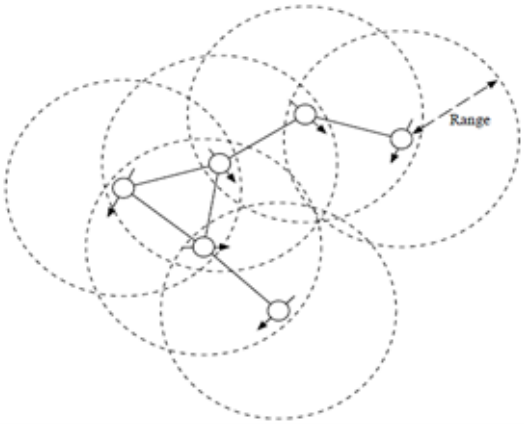

Fig. 2. Illustration of the infrastructure-less network

The history of Mobile Ad hoc Networks can be traced back to 1972 and the U.S Department of Defense (DOD) sponsored Packet Radio Network (PRNET), which evolved into the Survivable Adaptive Radio Networks (SURAN) program in the early 1980s. ARPANet first introduced packet switching technology in the 1960s, it was not until the growth of the Internet infrastructure and the microcomputer revolution that packet radio network ideas became truly applicable and feasible. One of the original motivations for MANET is found in the military need for battlefield survivability. Soldiers must be able to move freely without any of the restrictions imposed by wired communication devices. An additional motivation for MANET is that the military cannot rely on access to a fixed, pre-placed communications infrastructure in battlefield environments. Therefore, the goal of the DoD sponsored programs was to provide packet-switched networking to mobile battlefield elements in an infrastructure less, hostile environment (such as soldiers, tanks, aircraft, etc.) forming the nodes in the network. The packet radio was the first implementation of an infrastructure less network where nodes are mobile devices. The MANET has played an important role in military applications and related research efforts, for example, the global mobile information systems (GloMo) program and the near-term digital radio (NTDR) program. Recent years have seen a new spate of industrial and commercial applications for wireless ad hoc networks, as many portable computers and personal digital assistants (PDAs) equipped with wireless ports are becoming more compact and inexpensive

A. Evolution of MANET:

In 1970, Normanl Abramson and his fellow researchers at the University of Hawaii invented ALOHAnet.
In 1972 DARPA Packet Radio Network (PRNet).
In 1980 Survivable Radio Networks (SURAN).
During 1980 emergence of Internet Emerging Task Force (IETF), termed the mobile ad hoc networking group.
In 1994 emergence of Bluetooth by Ericsson.

B. Characteristics of Mobile Ad Hoc Networks:

The main characteristics of the MANETs are dynamic topology, bandwidth constrained, variable capacity links, energy constrained operation, limited physical security and quickly deployable.

***C. Applications of Mobile Ad Hoc Networks*:**

The following are some well-known applications **[1][2]** of MANET are described given below

1) Military

- Automated battlefield
- Special operations
- Homeland defense

2) Civilian

- Disaster Recovery (flood, fire, earthquakes etc)
- Law enforcement (crowd control)
- Search and rescue in remote areas
- Environment monitoring (sensors)
- Space/planet exploration

3) Commercial

- Sport events, festivals, conventions

- Patient monitoring
- Ad hoc collaborative computing (Bluetooth)
- Sensors on cars (car navigation safety)
- Car to car communications
- Networked video games at amusement parks, et

D. Research Challenges:

Mobile Ad Hoc Networks (MANETs) has become one of the most prevalent areas of research in the recent years because of the challenges it pose to the related protocols. The MANET is the new emerging technology, which enables users to communicate without any physical infrastructure regardless of their geographical location the following are research areas in the MANET**[1][2].**

- Reliability
- Routing
- Scalability
- Security
- Internetworking
- Multimedia
- Energy consumption optimization
- Quality Of services
- Multipath Routing
- Cross layer design
- Unicast, Multicast, Broadcast, Geocast routing protocols design
- .MAC protocol design, Network layer Transport layer and application layer design
- Next generation hydride network protocols

II. MOTIVATION TO ROUTING IN THE MANET

Routing protocols used in wired networks cannot be directly applied to ad hoc wireless networks due following reasons.

- Highly dynamic topology
- No infrastructure for centralized administration
- Bandwidth constrained
- Energy constrained
- Hidden and exposed problem
- Error prone wireless channel
- Poor wireless variable link capacity

These routing protocols in MANET can be classified into two main categories namely table driven routing protocol and on-demand routing protocol. The table driven routing protocol also called proactive routing protocols **[4][5].** In Table-driven routing protocols each node computes route to all other nodes in network in advance, each node maintains one or more tables containing routing information to every other node in the network. All nodes update these tables so as to maintain a consistent and up-to-date view of the network. When network topology changes the nodes propagate and update messages throughout the network in order to maintain consistent and up-to-date routing information about the whole network. Some well known and standard table driven protocols are as follows

- Wireless Routing Protocol (WRP)
- Global State Routing (GSR)
- Fisheye State Routing (FSR)
- Hierarchical State Routing (HSR)
- Zone Based Hierarchical LSR Protocol (ZHLS)
- luster Switch Gateway Routing (CGSR)
- Destination Sequenced Distance-Vector Protocol (DSDV)

The on-demand routing protocols build routes only when a node needs to send the data packets to a destination by invoking the route discovery. Some of the well known and standard on demand routing protocols are as follows

- Dynamic Source Routing (DSR)
- Cluster Based Routing Protocol (CBRP)
- Ad-hoc On-demand Distance Vector Routing Protocol (AODV))
- Temporally Ordered Routing Algorithm (TORA)
- Associatively Based Routing (ABR)
- Signal Stability Based Adaptive Routing (SSR).

The on-demand routing is the most popular approach in the MANET compare to table-driven routing , instead of periodically exchanging route messages to maintain a permanent route table of the full topology the maintenance of whole information about network topology in routing tables is eliminated and the dissemination of routing information throughout the network is also eliminated because that will consume a lot of the scarce bandwidth and power when the link state and network topology changes rapidly and it also works well when network size increases .

A. Motivation to Multipath Routing:

The most existing on demand routing protocols build and utilize only one single route for each pair of source and destination nodes **[6].** A fundamental problem in ad hoc networking is how to deliver data packets among nodes efficiently without predetermined topology or centralized control, which is the main objective of ad hoc routing protocols. Due to node mobility, node failure, and the dynamic characteristics of the radio channel, links in a route may become temporarily unavailable and making the route invalid. The overhead of finding alternative routes may be high and extra delay in packet delivery may be introduced. The Multipath routing addresses this problem by providing more than one route to a destination node. Source and intermediate nodes can use these routes as primary and backup routes. Alternatively, the traffic can be distributed among multiple routes to enhance transmission reliability, provide load balancing and secure data transmission. The Multipath routing effectively reduces the frequency of route discovery therefore the latency for discovering another route is reduced when currently used route is broken. The multipath routing appears to be a promising technique for ad hoc routing protocols. Providing multiple routes is beneficial in communications, particularly in the MANETs where routes become obsolete frequently because of mobility and poor wireless link quality. Multiple paths can be useful in improving the effective bandwidth of communication, responding to congestion and heavy traffic, and increasing delivery reliability.

B. Benefits of multipath routing:

In this section outline some of the applications of multipath routing that improve network performance [6][7].

***1) Reliability*:** By "reliability" we mean the probability that a message generated at one place in the network can actually be routed to the intended destination. Reliability is a big challenge in MANETs because packets transmitted are subject to lost due to frequent topological changes, severe media access conflicts, and various kinds of interferences that affect the wireless transceivers to correctly decode the wireless signals. Multipath routing in a MANET was originally developed as a means to provide route failure protection.

***2) Fault tolerance*:** Multipath routing protocols can provide fault tolerance by having redundant information routed to the destination via alternative paths. This reduces the probability that communication is disrupted in case of link failure. More sophisticated algorithms employ source coding, to reduce the traffic overhead caused by too much redundancy, while maintaining the same degree of reliability. This increase in route resiliency is largely depended on metrics such as the diversity, or *disjointness*, of the available paths.

***3) Balancing Of Load*:** Most of the on-demand routing protocols tend to have their routing load concentrated on a few centrally located nodes. This causes network congestion and bottlenecks as large number of node route through these heavily loaded nodes. One solution to this problem is to have a routing strategy that could balance and distribute the traffic load more evenly to each mobile node. The main aim to develop load balancing strategies that could dynamically monitor any changes to the load status of the surroundings and be able to choose the least loaded routes dynamically with the knowledge of the surrounding load status. When a link becomes over-utilized and causes congestion, multipath routing protocols can choose to divert traffic through alternate paths to ease the burden of the congested link.

***4) Bandwidth aggregation*:** By splitting data to the same destination into multiple streams, each stream is routed through a different path, the effective bandwidth can be aggregated. This strategy is particular beneficial when a node has multiple low-bandwidth links but requires a bandwidth greater than an individual link can provide. End-to-end delay may also be reduced as a direct result of larger bandwidth.

***5) Reduced delay*:** For wireless networks employing single path on-demand routing protocols, a route failure means that a new path discovery process needs to be initiated to find a new route. This results in a route discovery delay. The delay is minimized in multipath routing because backup routes.

***6) Energy Consumption*:** Nodes in a MANET are typically powered by batteries which have limited energy reservoir. In some application scenarios, replenishment of power supplies might not be possible. The lifetime of the nodes show strong dependence on the lifetime of the batteries. In the multihop MANET nodes depend on each other to relay packets. The lost of some nodes may cause significant topological changes, undermine the network operation, and affect the lifetime of the network. Energy efficient routing has been the subject of intensive study in recent years.

***7) Reduction of Routing Overhead*:** Another benefit of multipath routing is the reduction of the routing overhead by reducing the number of route discoveries.

8) To Provide Quality of Service: An important objective of multipath routing is to provide quality of service, more specifically, to reduce the end-to-end delay, to avoid or alleviate the congestion, and to improve the end-to-end throughput.

9) To Improve Network Security and Secure communication: The MANETs are exposed to all kinds of attacks. A fundamental problem is how to deliver data packets among nodes confidentially and efficiently without predetermined topology or centralized control in the insured MANET. In such an open hostile environment where there is a need of network

security services that can provide secure communication in such public network is most significant. If data packets are distribute to single path the attacker can attack is possible. Multipath avoid this by distributing data packets through multiple path from source to destination some well known standard Multipath path routing Protocols are identified during route discovery.

The several multipath on-demand routing protocols were proposed. Some well known standard Multipath path routing Protocols are

- Ad hoc On-demand Distance Vector Multipath Routing (AODVM)
- Ad hoc On-demand Multipath Distance Vector (AOMDV)
- Split Multipath Routing (SMR)
- Multipath Source Routing (MSR

Table.1 Comparison of On demand Multipath Routing Protocol

	AODVM	AOMDV	SMR	MSR
Loop-Free paths	No	No	No	No
Node Disjoint	Yes	No	No	Yes
Routing Overhead control	No	No	No	No
Complete Routes Known at source	No	No	Yes	Yes
Multipath used Simultaneously	Yes	Yes	Yes	Yes
TTL limitation	Yes	Yes	Yes	Yes
QOS Support	No	No	No	No
Multicast Support	No	No	No	No
Power Management	No	No	No	No
Security Support	No	No	NO	No

The Zhenqiang Krishnamurthy and Tripathi **[8]** proposed the Ad hoc On-demand Distance Vector Multipath Routing(AODVM) is based on AODV for finding multiple node disjoint paths **[9].** The Mahesh and Samir R.D proposed Ad hoc On-demand Multipath Distance Vector (AOMDV) is an extension to the AODV protocol for computing multiple loop-free and link-disjoint paths[9]. The Lee and Gerla proposed the Split Multipath Routing (SMR) **[10]** is an on-demand multipath source routing protocol that builds multiple routes using a request/reply cycle, it can find an alternative route that is maximally disjoint from the source to destination. The Wang, Shu, et proposed the Multipath Source Routing(MSR) **[11]** ,it is an extension of the DSR protocol and it distributes traffic among the multiple routes in a network , table 1 shows comparison above protocols

III. ENERGY AWARE ON DEMAND MULTIPATH ROUTING PROTOCOLS

A) The nodes in the MANET are constrained by limited battery power for their operation. Hence, energy management is in important issue in such networks. The use of multi-hop radio relaying requires a sufficient number of relaying nodes to maintain the network connectivity. Hence, battery potter is a precious resource that must be used efficiently in order to avoid early termination of any node. Energy management deals with the process of managing energy resources by means of controlling the battery discharge, adjusting the transmission power, end scheduling of power sources so as to increase the lifetime of the nodes of an ad hoc wireless network **[2].** Efficient battery management, Transmission power management, and system power management are the three major means of increasing the life of a node. The energy efficient routing is the most important design criteria for MANETs since mobile nodes will be powered by the batteries with limited capacity. The power failure of a mobile node not only affects the node itself but also its ability to forward the data packets on behalf of others and thus the overall network lifetime. For this reason, many research efforts have been devoted to developing energy aware on demand multipath routing protocols that are described as follows

1) authors proposed Power-aware source routing protocol for mobile ad hoc networks[12], this paper presents a new source-initiated (on-demand) routing protocol for mobile ad hoc networks that increases the network lifetime. Simulation results show that the proposed power-aware source routing protocol has a higher performance than other source initiated routing protocols in terms of the network lifetime.

2) Minimum Energy Disjoint Path Routing in Wireless Ad-hoc Networks **[13**] in this paper, the authors presented a novel polynomial time algorithm that finds a pair of minimum energy link-disjoint paths in a wireless network. In addition, they presented an optimal algorithm that solves the minimum energy k node-disjoint paths problem in polynomial time, as well as fast, but sub-optimal heuristics for both problems. The results show that link-disjoint paths consume substantially less energy than node-disjoint paths. They also found that the incremental energy of additional link-disjoint paths is decreasing. This finding is somewhat surprising due to the fact that in general graphs additional paths are typically longer than the shortest path. It is also determined that for the case of node-disjoint paths, the energy savings due to the use of the optimal algorithm (over a sub-optimal heuristic) was most notable in sparse graphs (i.e., N small); while for the link-disjoint case the energy savings were most notable in dense graphs**.**

3) This paper presents Multipath Power Sensitive Routing (MPSR)[**14]** protocol that builds multiple routes between the source and the destination nodes and uses a heuristic to switch between routes such that the burden of routing is distributed evenly to all the nodes in the network. The authors believe that every node in the network must be treated equally for the stability of the network. This paper aims to achieve this stability by maintaining the variance of the remaining power of each node as low as possible so that the mean time to failure of the nodes increases**.**

4) Rate the Optimal Allocation for Energy-Efficient Multipath Routing in wire Mobile Ad Hoc Networks**[15],** this paper addresses the problem of energy efficiency in wireless ad hoc networks. The author considers an ad hoc network comprising a set of sources, communicating with their destinations using multiple routes. Each source is associated with a utility function this increases with the total traffic flowing over the available source-destination routes. The network lifetime is defined as the time until the first node in the network runs out of energy. The authors formulate the problem as one of maximizing the sum of the source utilities subject to a required constraint on the network lifetime. They present a primal formulation of the problem, which uses penalty functions to take into account the system constraints and a new methodology was introduced for solving the problem. The proposed approach leads to a flow control algorithm, which provides the optimal source rates and can be easily implemented in a distributed manner. When compared with the minimum transmission energy routing scheme, the proposed algorithm gives significantly higher source rates for the same network lifetime guarantee**.**

5) An Energy-Aware Multipath Routing Protocol for Mobile Ad Hoc Networks**[16],** in this paper, a cross-layer optimized energy-aware multipath routing protocol (EMRP) for mobile ad hoc networks (MANET) is proposed. By sharing the information among the physical layer, the MAC sub-layer and the network layer, the EMRP efficiently utilizes the network resources such as the node energy and the link bandwidth. Simulation results show that the protocol prolongs the network lifetime, increases the volume of packets delivered, lowers the energy dissipation per bit of data delivery and shortens the end-to-end delay.

6) The Multipath Energy-Efficient Routing Protocol (MEER)[**17]** prolongs the network lifetime by using a rational power control mechanism, the route discovery phase in which the source is finding energy-efficient routes is similar to that of SRM (Split Multipath Routing) protocol. The proposed MEER (Multipath Energy-Efficient Routing) protocol, based on SMR, considers the energy consumption when establishing a route. The MEER protocol consists of three phases, i.e., i) the route discovery phase in which the source node searches for the routes to the destination node, ii) the route selection phase in which the proper routes are selected among several candidate routes and ii) the route maintenance phase.

7)The Lifetime-Aware Multipath Optimized Routing (LAMOR**[18]** is based on the lifetime of a node which is related to its residual energy and current traffic conditions, it support high-speed real time video transmission in the MANET, which is optimized in terms of lifetime and analyze its characteristics. In the LAMOR, the rate allocation is optimized for a group of video frames at a time, over multiple paths. In this paper, the authors investigate the problem of optimal rate allocation among multiple paths to maximize the lifetime of the routes by evenly load distribution among multiple paths. The optimization is performed via dynamically distributing rate in terms of the changing bottleneck node's lifetime, where the lifetime of each node is computed by its residual energy, current traffic conditions and the required energy consumed for sending a packet to its next hop in the path. The factors considered in computing the lifetime of a node will avoid the congestion and the energy over used of a node, so to provide strongly reliable paths for data transmission and improve the video quality.

8) An Energy Aware Source Routing (EASR) with Disjoint Multipath Selection for Energy-Efficient Multihop Wireless Ad hoc Networks **[19]** is efficient from network long-term connectivity point of view. In this algorithm, multiple routing paths are selected. However, only one path will be used for data transmission at a certain time among multiple paths and each path has probability to be selected. In the EASR, the routing paths will be discovered without overlapped. In addition, each path hardly overhears other data transmission, in which overhearing ratio is defined in order to reduce the overhearing energy waste among each selected path. The how establish energy efficient multiple paths are showed by making use of overhearing ratio and the simulation results show that the proposed scheme can achieve magnitude improvement of network lifetime and reasonable packet latency time.

9) The Grid-Based Energy Aware Node-Disjoint Multipath Routing Algorithm (GEANDMRA)**[20]** considers energy aware and node-disjoint multipath**,** In this paper, grid partitioning is the same as in the GRID routing protocol. The main difference between these two protocols is that GEANDMRA considers energy aware and node-disjoint multipath but the GRID does not. It uses grid-head election algorithm to select the grid-head which is responsible for forwarding routing information and transmitting data packets.

10) The Ant-based Energy Aware Disjoint Multipath Routing Algorithm.(AEADMRA) **[21]** is proposed. It is based on swarm intelligence and especially on the ant colony based meta heuristic, it extends GRID to enable path accumulation in route request/reply packets and discover multiple energy aware routing paths with a low routing overhead. Simulation results indicate that performance of the AEADMRA is much better than that of the GRID.

11) Directional Antenna Multipath Location Aided Routing with On Demand Transmission Power **[22]** this paper studies a Directional Antenna Multi-path Location Aided Routing (DA-MLAR) scheme with on demand transmission power support. The targeted application contexts include communications in space networks, where efficient and reliable packet delivery is very challenging due to the high bit error rate, intermittent connectivity, limited bandwidth and energy. It enhances the DA-MLAR protocol with On Demand Transmission Power (ODTP) capability. By using different transmission power based on

the calculated distance from the current sender node to the destination node or the next hop node. The DA-MLAR-ODTP gets the best of the directional and omni-directional modes compared to DA-MLAR, on demand transmission power mode further improves the packet delivery ratio by up to 37% end-to-end delay by up to 57% with more or less the same amount of energy consumption. Simulation experiments show that this is a promising technique for more reliable communications in MANET with energy and other constraints.

12) Energy-Aware Grid Multipath Routing Protocol in MANET **[23]** in this protocol has two methods the Gateway Election and Maintenance methods, each host uses its unique ID. One mobile host in each grid will be elected as the gateway. The gateway host must maintain a host table that stores the host ID and status (transmit/sleep mode) of all the hosts in the same grid and a neighbor table that stores information of gateway's neighbors in the same grid. The gateway is responsible for forwarding routing information and transmitting data packets. It plays the most important role in the EAGMR. In this paper, the authors has proposed to use node degree and node's remaining energy in each gird as the primary key to select gateway. The node with higher node degree is more stable and the node's remaining energy which is bigger than an energy threshold just can guarantee efficient routing. The proposed protocol can conserve energy and provide the best path to route according to probability. Simulation results indicate that this new energy-aware protocol can save energy of mobile hosts and improve data packet delivery ratio.

13) Power-Aware Multi-Path Routing Protocol (PAMP)**[24]** is an extension of the existing AODV by modifying RREQ and RREP management mechanism to handle energy reservation and multiple paths. outstanding example of distance vector routing protocol. It focuses on establishing multiple paths with the nodes whose energy is not sufficient to forward the whole packets of a session. PAMP introduces following four features into AODV. First, energy and multi-path related information fields in RREQ and RREP, second, duplicate RREQs management, third, energy-based route selection at the destination, and, last, energy management during date delivery. We introduce three new information fields in the RREQ such as Ereq, Epath, and HopCount. The Ereq is the expected number of bytes to be transmitted by the source. It will be used by the destination as a condition for multipath selection. The Epath represents the minimum number of bytes supported by the path. Initially it will be the same as Ereq, it is updated according to the available energy of the RREQ processing node. The HopCount is the number of intermediate nodes RREQ has passed. Initially, it will be zero and incremented by one per node. It is used to decide whether to process additional RREQ or not. The RREQ has a sequence number (SN) field as an identifier. In the original AODV, it is not modified until the RREQ reaches the destination. In PAMP, it is updated by the forwarding node and used to identify the upstream node when the corresponding RREP is forwarded in the reverse direction. The destination node determines the proper set of paths and the amount of energy to be reserved on each path. The intermediate nodes of the path will be informed by the RREPs. Our scheme introduces additional fields in the RREP, such as Eresv and SNRREQ. The Eresv is the energy to be reserved on the path.It is represented as capacity of the decided path. *SNRREQ* is the copy of the SN of RREQ corresponding to the path. With this *SNRREQ*, the RREP receiving node can determine the upstream node.

14) In **[25],** the authors suggested an energy efficient multipath routing protocol for mobile ad hoc networks, called MMRE-AOMDV, which extends the standard AOMDV routing protocol. The main idea of the protocol is to find the minimal nodal residual energy of each route in the route selection process and arrange multi-route by descending nodal residual energy. Once a new route with greater nodal residual energy is emerging, it is reselected to forward rest of the data packets. It can balance individual node's energy consumption and hence prolong the entire network's lifetime.

15) Energy Aware Node Disjoint Multipath Routing (ENDMR) in Mobile Ad Hoc Network **[26]** protocol significantly reduces the total number of route request packets, this result in an increased packet delivery ratio, decreasing end-to-end delays for the data packets, lower control overhead, fewer collisions of packets, supporting reliability and decreasing power consumption. Each route request carries the cumulative cost, so very little bit overhead is increased to carry the cumulative cost but it is negligible. The ENDMR has the following desired features. It is based on standard on demand routing protocol i.e. the Dynamic Source Routing (DSR**)** enhanced to provide multiple routes and it uses new power aware metric i.e. minimum node cost to find the optimal paths. Due to on-demand nature, the maintenance of whole information about network topology in routing tables is eliminated and the dissemination of routing information throughout the network is also eliminated because that will consume a lot of the scarce bandwidth and power when the link state and network topology changes rapidly and it also works well when network size increases. It reduces the overhead during broadcasting of route requests using a novel approach, which in turn induces little bit overhead to carry node's cost in route quest. It supports node-disjoint multiple paths for reliability, and congestion control. It supports stability i.e. it increases mean time to failure of the nodes by distributing the burden of routing. The computation of optimal paths is assigned to destination node instead of source node to reduce the overhead. In conventional protocols; source node computes optimal paths from multiple paths that were supplied by destination node. Due to this overhead increases because if sending many multiple paths back to source, the lot of bandwidth and power are wasted and delay also increases. It has many qualitative properties and desired futures. It is performance is analyzed using various parameters.

16) Energy Aware Clustered Based Multipath Routing (EACMR) **[27]** proposed novel approach (EACMR) is very suitable and applicable for the cluster based mobile ad hoc networks. It is not based on GPS. It can be applied to a mobile ad hoc network that is using any clustering scheme. In this work, the CONID clustering scheme is used as back-ground to form clusters, instead of that any clustering scheme may be used to form clusters in the network. The EACMR is designed to find energy aware node- disjoint multiple routes from a source to a destination through clusterheads. It increases the network life

time by using optimal routes, as compare to on demand mul-tipath routing protocols, it significantly reduces the total number of route request packets using clustering technique, this result in an increased packet delivery ratio, decreasing end-to-end delays for the data packets, lower control overhead, fewer collisions of packets , de-creasing power consumption. It supports the reliability by using multiple node-disjoint paths.

17) Power-Aware Node-Disjoint Multipath Source Routing(PNDMSR) with Low Overhead in MANET **[28]** protocol significantly reduces the total number of route request packets, this result in an increased packet delivery ratio, decreasing end-to-end delays for the data packets, lower control overhead, fewer collisions of packets, supporting reliability and decreasing power consumption. Each route request carries the cumulative cost, so very little bit overhead is increased to carry the cumulative cost but it is negligible. It is based on standard on demand routing protocol i.e., DSR has extended to support multipath and it uses new power aware metric i.e., minimum node cost to find the optimal paths. Due to on-demand nature, the maintenance of whole information about network topology in routing tables is eliminated and the dissemination of routing information throughout the network is also eliminated because that will consume a lot of the scarce bandwidth and power when the link state and network topology changes rapidly and it also works well when network size increases. It reduces the overhead during broadcasting of route requests using a novel approach, which in turn induces little bit overhead to carry node cost in route quest. It supports node-disjoint multiple paths for reliability, and congestion control. It supports stability i.e. it increases mean time to failure of the nodes by distributing the burden of routing. The computation of optimal paths is assigned to destination node instead of source node to reduce the overhead. Where as in the conventional protocols; source node computes optimal paths from multiple paths that were supplied by destination node. Due to this overhead increases, because if sending many multiple paths back to source, a lot of bandwidth and power are wasted and delay also increases for real-time traffic, which balances the node energy utilization to increase the network lifetime. It takes the network congestion into account to reduce the routing delay across the network, and increases the reliability of the data packets reaching the destination

18)The authors proposed an optimized energy aware routing called OEAR in MANET **[29]** it finds the most stable path out of the entire existing paths from source to destination using on-demand routing, which takes into account energy of the node and the number of packets buffered in the node while selecting the route.

19) Energy Aware and Multipath Base Reliable Communication in MANET [**30]** in this paper authors proposed a multi-path MAX energy based routing scheme that reduces the congestion and improves the energy efficiency and the reliability in data delivery. In this scheme the multipath AOMDV protocol reduces the possibility of congestion by using the concept of dynamic queue and MAX energy based routing always selecting the node for routing that has maximum energy. Each data packet is delivered to the neighbor by one or more multiple paths according to proposed scheme. The balance among multiple paths that considers the energy usage at neighbors is further considered in path selection, which leads to efficient utilization of the relay nodes and prevents early death of heavily involved nodes. Simulation results show that proposed energy aware path selection, a more even MAX energy consumption among nodes is developed and leads to longer network life time.

20)The Link Stability with Energy Aware(LSEA) Ad hoc On Demand Multipath Routing Protocol in Mobile Ad Hoc Networks **[31]** , in this paper author consider the communication links between nodes and energy of nodes, that are very important factor for improving quality of routing protocols. This study presents innovative Link Stability with Energy Aware (LSEA) multipath routing protocol. The key idea of the protocol is find the link quality, maximum remaining energy and lower delay. Reflections of these factors are increasing the qualities like packet delivery ratio, throughputs and reduce end-to-end delay.

21) Energy Enhancement in AOMDV **[32],** it is extension of the AOMDV, in which route discovery procedure to enable computation minimal nodal residual energy of each route between source-destination pairs. Each RREQ and RREP now carries an additional field called *min re-energy to* indicate that all of nodes in the route have the minimal nodal residual energy. When intermediate node receives RREQ packet, only if the sequence number of just received packet is greater than this node', its residual energy should be compared with the min_re_energy of RREQ. *If the residual* energy of this node is less than the min_re_energy of RREQ, then update the *min_re_energy field with it, in order to keep the* value of min_re_energy lowest among all the nodes in this route.

22) Energy Efficient Power Aware Multipath Dynamic Source Routing (DSR-SR**) [33]** is modified version of one of the most popular routing protocols that is Dynamic Source Routing (DSR) protocol which is not at all concerned about power consumption. The proposed Dynamic source routing-Power Aware routing DSR-PSR uses the basic concept of traditional DSR and implements energy efficient routing through which it not only enhances the life time of the network but also increases the overall performance of the networks.

23) Energy Efficient Multipath Routing for Mobile Ad Hoc Networks **[34]** in this paper, authors propose an energy efficient multipath routing protocol for choosing energy efficient path. This system also considers transmission power of nodes and residual energy as energy metrics in order to maximize the network lifetime and to reduce energy consumption of mobile nodes. The objective of our proposed system is to find an optimal route based on two energy metrics while choosing a route to transfer data packets.

24) Energy Conservation for Ad Hoc On-Demand Distance Vector Multipath Routing Protocol **[35]** it and extension of the well-known routing protocol AODVM (Ad hoc On-demand Distance Vector Multipath) is called as AODVME+. In this

approach alternate paths are pre-computed, and when there is a link failure, one of the alternate paths is used (if at least one is available) to forward the data packets. The choice of the path depends on the weighted sum of all the paths found. The minimum residual energy and the average path energy are the terms used to calculate this weighted sum. By computer simulation, the performance of the AODVME+ was evaluated and compared it with the AODVM and MMRE protocols. Simulation results have shown that the proposed protocol consumes less energy, has a lower average end-to-end delay and minimizes the overhead traffic and it is concluded that our protocol AODVME+ improves the network performance. It improves the multipath routing strategy with a path classification to allow the paths with the best energy level to be chosen.

25) In this paper **[36]** authors proposed an optimized energy efficient routing scheme by slightly modifying MMRE-AOMDV route update rules in order to generate more energy efficient routes than MMRE-AOMDV routing protocol, called an Optimized Minimal Maximal nodal Residual Energy AOMDV (OMMRE-AOMDV) protocol. It reduces the energy consumption, average end to end delay, routing overhead and normalized routing overhead. It also improves packet delivery ratio and throughput. Simulation results show that the OMMRE-AOMDV routing protocol has performed better than AOMDV and MMRE-AOMDV routing protocols.

26) Enhanced Power aware Multipath Routing (EPMR) **[37]** The EPMR protocol combines the concepts of multipath as well as power aware routing to discover multiple paths between a pair of source to destination the basic route discovery mechanisms used in AODV protocols. The paths selected based on highest average energy of the nodes in the route and the route containing highest minimum energy level in the route. . When a source need to send packets to one destination, using this protocol multiple paths are selected with minimum hop count and maximum lowest energy level. According to this criterion the route information will be stored and the best path which satisfies the above criteria will be considered as the optimal path, next best path will be the secondary path and so on. So whenever there occurs any link or node failure, then the source node switches to the next optimal path. This reduces the need of re- route discovery process which is a time consuming process. The paths are node disjoint paths which also make the network more reliable and avoid the condition of over utilization of the same node for different routes. The EPMR Efficiently utilizes the energy of nodes and resources thus increases reliability and the lifetime of the network

IV. CONCLUSIONS

The MANET is one of the most important and essential technology that support pervasive computing scenario. The special characters of the MANET bring this technology great opportunity together with several challenges. Currently the MANET is becoming more interesting research area and many research projects employed by academic and companies all over the world.

In this paper, We have surveyed total twenty six different energy aware on-demand multipath routing protocols in detail but also described the introduction to MANET, application, research challenges, single path routing and multipath routing protocols. We hope that this very useful and helpful to research community in the MANET.

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