

# A Parametric Oriented Research on Routing Algorithms in Mobile Adhoc Networks



P. Shailaja, C.V. Guru Rao, A.Nagaraju

**Abstract:** Due to the infrastructure-less and no central administration architecture, Mobile Adhoc Networks (MANETs) gained significant interest in various wireless information transfer related applications. However, the selection of an optimal path to transmit the data is a more critical issue in MANETs because the nodes are resource-constrained and also have mobility. To provide an optimal solution to this constraint, various methods are proposed in earlier. Initially, some basic routing protocols are developed and further by modifying the base protocols so many strategies are developed. The proposed Research paper outlines a detailed survey about the earlier developed such strategies and also done a fined classification based on the methodology they followed. Broadly the comprehensive routing approaches are classified into two classes, namely single metric-based approaches and multiple metrics-based approaches. The further classification is done based on the routing protocol used at the base. Due to the widespread utilization of meta-heuristic algorithms, some authors used those techniques also in the discovery of an optimal path and some approaches are outlined in this paper. Moreover, at every phase, a fine and detailed comparison is shown through various constraints.

**Keywords:** Mobile Adhoc Networks, Proactive, Reactive, Single metric, multiple metrics, Energy, Mobility, Delay.

## I. INTRODUCTION

With great advancement in Information and Communication Technology (ICT), Mobile AdHoc networks (MANETs) have gained a lot of importance in various applications like Disaster Management, Military communications, Health Monitoring, Remote Education, Visual Surveillance, etc. An autonomous and dynamic communication paradigm is required in several advanced applications to provide a faster service. MANETs are the best solution for this kind of applications in which the mobile devices are integrated and formulated into an infrastructure-less network. Generally, A MANET is a network formulated with a set of mobile devices that can communicate with each other across multiple hops in a distributed fashion [1].

Since the mobile devices connected to MANET are smaller, cheaper, portable and also have a widespread utilization in the real world, MANETs have become a growing and promising solution for various benchmark standard applications. A simple representation of MANET is shown in figure.1.

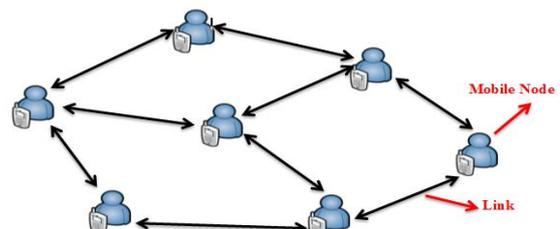


Figure.1 An example of MANET

Some of the applications of MANETs are listed below;

1. Business and Commercial applications
2. Crisis management applications
3. Personal area networking applications
4. Residential Mesh Networks
5. Vehicular Applications
6. Military Applications

## A. Characteristics of MANETs

The infrastructure-less MANETs have the following characteristics [2];

1. **Self-organizing nature:** MANETs are infrastructure-less in nature and there is no centralized administration. Every node in the network has a self-organizing capability according to the requirements.
2. **Resource Consumption:** In MANETs, the mobile nodes are smaller in size and hence the energy capacity is also less. The design of a resource-effective communication is a serious problem in MANETs. Since the mobile devices are resource-limited, a continuous working mode makes these nodes quick to die. Along with energy, the bandwidth links and memory are also limited to these devices.
3. **Frequent changes in topology:** Since the devices in MANETs are free to move, there occur frequent changes in the network topology. Links established between the nodes will break up more frequently with these topological changes. For a MANET with high mobile nodes, the link breakages are more frequent and it is a more serious issue which a significant effect on the network.
4. **Multi-hopping:** due to the scarce resources, the nodes in MANETs will seek the help of other mobile nodes that are in their vicinity.

A co-operative communication between these nodes constitutes a multi-hop communication. This is much helpful in the large distance communication where the source and destination nodes are kept very far. Figure.2 shows the process of Multi-

Revised Manuscript Received on November 30, 2019.

\* Correspondence Author

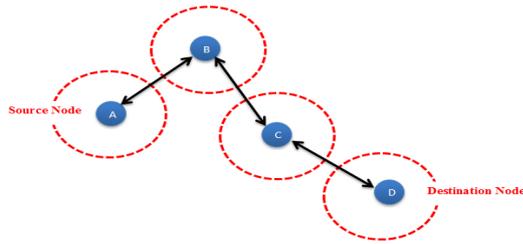
P. Shailaja\*, Research Scholar, JNTU Hyderabad  
[pokalashylaja@gmail.com](mailto:pokalashylaja@gmail.com).

Prof. C.V. Guru Rao, Director, SREC, Warangal, India,  
[Guru\\_cv\\_rao@hotmail.com](mailto:Guru_cv_rao@hotmail.com)

Dr. A.Nagaraju, Assistant Professor, CURAJ, India,  
[nagaraju@curaj.ac.in](mailto:nagaraju@curaj.ac.in)

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

hopping in which the source node is A and the destination node is D and the remaining nodes B and C are hopping nodes. Source node A seeks the help of node B and Node C to communicate with destination node D.



**Figure.2 Multi-hopping**

**5. Scalability:** The major advantage of MANETs is scalability. The nodes in the MANET can have the freedom to enter and leave the network at any time. This property helps in the deployment of a MANET in various applications related to node density. For example, in some applications like a battlefield, the nodes may grow up to several thousand. Though the scalability can give promising results, they undergo several problems such as channel capacity, scalability. Since the mobile nodes are capacity constrained, they drain up quickly.

**6. Limited Security:** Compared to infrastructure oriented networks or wired networks, MANETs are more prone to various security threats. Since every node in the MANET can act as a router or packet forwarder for other neighbor nodes, there is a chance to compromise the nodes easily. Once the node compromised, it behaves maliciously and doesn't cooperate for proper network functioning [2].

Along with these characteristics, Quality of Service (QoS), the node mobility, the reliability of wireless link, scalability in multi-hop routing, multicast support, and the variations in the capabilities of mobile nodes are few more aspects which have a significant effect over the routing in MANETs. Hence, the routing mechanisms need to consider all these factors when they are developing new routing protocols especially for a distant source and destination communications. The deployed routing protocol has to select an optimal route for a given source and destination node pair such that the energy consumption must be less and also needs to achieve an effective QoS in terms of packet delivery, delay, and available bandwidth of link [3], [4].

### B. Metrics for Route Selection

Generally, the routing protocols in MANETs follows Energy-related routing metrics [5] because the Energy is the only one factor which was linked with all the objectives such as network lifetime, and QoS related objectives like Packet Delivery, end-to-end delay and the optimal utilization of bandwidths. Hence most of the earlier developed approaches [6] focused on the development of an Energy-efficient routing selection for a given source and destination node pair. Here some metrics are discussed which are considered by earlier approaches.

**1. Variance in the Residual Energy:** The energy left at the nodes after forwarding the data to further node can be defined as residual energy. It is calculated by subtracting the energy consumed from the energy at the initial state. Less residual energy indicates that the node is not capable of further data forwarding and vice versa. Since a node can be a multi-hop forwarder, more than one node may use it for data forwarding. In such a case, the variance in the residual energy indicates the node's further forwarding capacity.

However, this metric alone can't result in an efficient route [7].

**2. Energy consumption per packet:** In this aspect, the routing algorithm tries to reduce the energy at a packet level only. Here the total energy required for every packet is reduced by reducing the transmission power. But this metric can't ensure fruitful results, especially which it was deployed lonely.

**3. Node Mobility:** Node mobility [8], [9] is an important factor that needs to be considered during the route selection. For a mobile node with high mobility, there is a possibility of larger route breakups which results in an extensive packet loss. Further, to establish a new route, extra energy is required. Along with these effects, the network may also get partitioned if a mobile node moves out of the communication range of all nodes. However, a node mobility factor can't ensure the lowest energy path.

**4. Link Bandwidth:** The availability of less bandwidth over a selected link/ route results in more congestion followed by an increased end-to-end delay [10], [11]. Congestion becomes worst in the case of multimedia related data transmissions like image, speech, and videos. However, this metric not ensure the shortest and less energy consumption path.

Based on the above discussion, it is to be noted that a single metric is not a better choice for the selection of an optimal route to the destination nodes. Relatively, a mixture of multiple metrics will be more useful to discover an optimal route to the destination node. Furthermore, a composite route metric that involves multiple metrics associated with both QoS and energy would be more useful for the evaluation of routes and to achieve an extended network lifetime followed by a better QoS.

This paper investigates various routing techniques developed for MANETs. The different metric based approaches are there. In the first one, the node or path is selected based on only one metric and most of the earlier approaches used energy as a reference metric. In the next category, the node or path is selected based on multiple metrics such as energy, mobility, delay, and stability, etc. A fine classification is done in this paper with respect to proactive and reactive accomplishment also. Finally, some more approaches are listed which seek the help of artificial intelligence. The remaining paper is organized as follows; Section II discusses the basic protocols such as AODV, DSR, and OLSR, etc. This section also shows a comparison between the basic protocols through various constraints.

Section III discusses the complete details of the literature survey and this section is organized under three subsections such as single metric-based approaches, multiple metrics-based approaches, and learning-based approaches. Finally, the conclusions are given in section IV.

## II. BASIC PROTOCOLS

Under this section, initially, the basic routing protocols such as Proactive, Reactive and Hybrid are discussed. The classification is done based on the idea of how and at what time the route is discovered. Further, the literature survey is carried out over the earlier developed optimal route selection methods.

According to Proactive routing protocols, every mobile node has a routing table and it stores the updates of all the other nodes, whereas the reactive routing protocols acquire the updates whenever they required. Destination Sequence Distance Vector (DSDV) [12], Cluster Switch Gateway Routing (CSGR) [18], Wireless Routing Protocol (WRP) [16], Topology Broadcast Based on Reverse-Path Forwarding (TBRPF) [19], and Optimized Link State Routing (OLSR) [20] are the better examples for proactive routing protocols. Adhoc On-Demand Distance Vector (AODV) [15], Dynamic Source Routing (DSR) [14],

Temporarily Ordered Routing Algorithm (TORA) [13], Link Quality State Routing (LQSR) [21] and Dynamic MANET On-Demand (DYMO) [22] are the best examples of reactive routing protocols. Finally, Zone Routing Protocol (ZRP) [23], Zone-based Hierarchical Link State (ZHLS) [17] routing, Broader Gateway Protocol (BGP) [24], and Enhanced Interior Gateway Routing Protocol (EIGRP) [25] are the best examples for hybrid routing protocols. Since so many researchers were already done a vast survey over these basic routing protocols, this paper represents the complete details about these protocols in a very simple manner.

**Table.1 Comparison between basic classes of protocols through various routing constraints**

S. No	Routing Feature	Proactive	Reactive	Hybrid
1.	Basic routing theme	Preloaded information at every node	Acquires On-demand	Combined
2.	Route discovery	Table-driven	On-demand	Combined
3.	Power Required	High	Low	Medium
4.	Memory Required	High	Low	Medium
5.	Delay	High	Low	Medium
6.	Routing Overhead	Low	High	Medium
7.	Updates	Periodically not required	Required periodically	Depends
8.	Scalability	Low	High for large scale networks	Better for large scale networks
9.	Bandwidth required	High	Low	Medium
10.	Examples	DSDV, OLSR, CSGR, WRP, TBRPF	DSR, AODV, TORA, DYMO, LQSR	ZRP, ZHLS, BGP, EIGRP

### III. LITERATURE SURVEY

Since energy is an important factor for effective communication in MANETs, most of the researchers focused on the minimization of energy consumption at different levels like node level, transmission level, path level, etc. The main objective of almost all the routing approaches is to obtain an effective path for a given source and destination node pair under various constraints. An extensive survey is conducted under this section and the complete survey is classified into two classes such as Single metric based Routing and Multiple Metrics based Routing. The complete details are described in the following sections.

#### 3.1 Single metric

In this category, the routing establishment process is done based on only one metric and it is mostly the energy level of a mobile node. The methods described under this survey belong to both reactive and proactive protocols.

##### 3.1.1 Proactive Based Approaches

Among the proactive protocols, OLSR protocol has gained the most important and widely employed in most of the routing approaches. Several metrics are proposed by considering the OLSR as the base protocol for the selection of a Multi-Point Relay (MRP) or making the decisions in routing. Some more methods considered the OLSR for both aspects. Table.2 shows the comparative analysis between various approaches developed based on the proactive and single metric strategy.

Ghanem et al. [26] proposed a new version of the MPR selection mechanism with reference to OLSR protocol and residual energy of node is considered as a reference metric, in place of two-hop neighbors. In this approach, the nodes which have less residual energy are excluded from the selection of MRPs. Though this approach attained an increased lifetime of the network, this approach not focused on the drain rate of the node. Furthermore, other than

residual energy, this approach didn't consider for route computation.

Similarly, De Rango et al. [27] developed an "Energy Efficient OLSR (EE-OLSR)" by modifying the standard OLSR protocol. The MRP selection is accomplished based on the Energy Awareness of a node through the energy state. For every node, one heuristic value is assigned and either it can be low or high. This value is defined based on the battery level and the traffic facing it. Compared to OLSR, this approach has obtained a significant saving in energy consumption. For a MANET with larger density, this approach gained a greater performance but the EEOLSR produces a higher overhead which is not considered during the route establishment.

Fatima and Najib [28] proposed another version of the modified OLSR protocol by focusing on the reduction of energy consumption along with mobility management. This approach considered the lifetime and speed during the selection of MRP. Mobility management is the main advantage of this approach through which the effect of topology changes over the network is analyzed. However, to track the mobility, every node must a GPS receiver and it is not feasible for practical implementation.

In [29], a new energy model is proposed based on the availability of energy state information of mobile nodes. This approach used the energy levels of nodes as QoS metrics during the selection of a route. Further to obtain the state information regarding the energy status of a node, more accurately, this approach also proposed two prediction models such as prediction and smart prediction. However, the simple energy level is not efficient and this approach nor focused on the load balancing and also over other QoS related metrics like delay, jitter, etc.

Further, based on the energy, the method proposed in [30] tries to select an optimal MRP followed by an optimal path for a given source and destination node pair. Among the available paths between the source and a destination node, one path is selected as final based on min-max energy concept. Furthermore, this approach also modified the transmission power at the MAC layer such that the topology can be controlled. Though this approach is accomplished at MAC and network layers, it was not considered multiple energy-related metrics to obtain a better energy-efficient path.

One similar approach was proposed by Mahfouz and minet [31], called energy-efficient OLSR (OLSRE) based on the evaluation of cost that occurred during packet transmission. Here the cost is measured based on the energy consumed for packet transmission and reception. For every node, this approach measures the cost and compares it with a predefined threshold. If the cost is above the threshold, then only the node is selected as MRP. Furthermore, this approach also uses this cost metric for the route selection. Though this approach improves the network lifetime the residual energy was considered only at the selection if MRP but not for the computation is link cost.

The method proposed by Kunz [32] focused on the improvisation of network lifetime and also over the improvisation of the performance of the routing mechanism.

This approach proposed a new version of the standard OLSR protocol by introducing two modifications. One is at the selection of MRP and another is at the computation of route. These two modifications are very much helpful in discarding the node's with less battery capacity thereby improving the network lifetime. This method assumes that every node has information regarding the residual energy without any need to transmit the Transmission Control and HELLO packets, but it is an unrealistic case in real-time applications. Furthermore, this approach not focused on the main drawback of OLSR, i.e., the reduction of a higher number of TC messages through which most of the energy is wasted.

OLSR version 2 (OLSRv2) [40, 41] is an update and successor of OLSR. OLSRv2 follows the same mechanism of OLSR but it can provide a simplified exchange of messages between nodes followed by a flexible signaling framework. Compared to the general OLSR, the OLSR v2 have a new neighborhood discovery protocol and a generalized message/packet format. Based on OLSRv2, Jabber et al. [39] proposed a multipath battery aware routing (MBA-OLSR) protocol. This approach considered the remaining battery energy of the nodes for calculating the initial cost of the multiple links between source-destination pairs. However, this approach not focused on mobility and the variations in the network topology.

**Table.2 comparison of proactive single metric-based routing approaches**

Reference	Routing protocol	Metric	Advantages	Disadvantages
Graham et al. [26]	OLSR	Residual Energy	Reduced power consumption for the selection of MRPs	Neglected the drain rate during MRP selection
De Rango et al. [27]	EEOLSR	Minimum drain rate	Reduces the energy of MRP	Higher overhead at route establishment
Fatima and Najib [28]	OLSR	Minimum Energy-based hops	Changes in the network topology are analyzed due to the mobility management	Neglected the direction of mobility
Kunz, T., & Alhalimi, R. [29]	Energy-Aware OLSR	Energy level as QoS metric	Has obtained the state information regarding the energy status if ode more accurately to find the path.	Not concentrating on the energy during the selection of MRP
Benslimane, A [30]	EPA-OLSR	Transmission Power	Considered the both MAC and network layers and controlled the network topology through transmission power	Residual energy is not considered
mahfoudh and minet [31]	OLSRE	Cost based on the power consumed for transmission and reception	Improved network lifetime due to the power control through packets.	Not focused on the residual energy levels and node movement
Kunz [32]	EEV-OLSR	The residual battery level of the nodes	Extended network lifetime and prolonging the existence of a node in the network	Higher overhead due to the HELLO and TC packets transmission
Jabber et al. [39]	MBA-OLSR	remaining battery energy of the nodes	Balanced load over nodes due to the Multipath routing	not focused on the mobility and the topology variations

### 3.1.2 Reactive Based Approaches

AODV and DSR are the two most popular and widely used protocols under this category. Considering the AODV as base protocol, energy-saving AODV (ESAODV) protocol is proposed by Ren P et al. [33] in which the source node collects the data regarding the energy levels of its neighbor nodes in the route discovery process. In this approach, after receiving the Route Request (RREQ) Packets, the intermediate nodes compare the energy level of the source node with a standard threshold. The threshold is derived as the average energy of the network and if the current energy of the source node is higher than the threshold, then only the intermediate node forwards the packets. However this approach is not suitable for heavy

traffic loads because in such case eve the source node has higher energy, it will get drain up quickly.

Next, based on the DSR protocol two approaches are proposed by Tarique and Tepe [34,35] namely "Minimum Energy Dynamic Source Routing (MEDSR)" and "Hierarchical Minimum Energy Dynamic Source Routing (HMEDSR)". These two approaches accomplished the modification of control packets to reduce energy consumption. The source node initially tries to find a link with less energy level followed a route with all links having minimum energies. However, the MEDSR has a disadvantage is that the packet flooding technique used for route discovers has produced significant overhead. Further, the HMEDSR controlled this overhead by reducing the MAC packets and control packet.

But, these approaches not focused on mobility management which has a significant impact on the control packets management.

Considering the different wireless interface of mobile nodes, a Power-Aware Heterogeneous Routing based on AODV (PHAODV) is proposed by Safa H et al. [36]. This approach considered the battery status of nodes when constructing a routing table. Further, for a choice of multiple routes between two nodes, a route with minimum power is chosen and the nodes of that route are added into the routing table. However, for a heterogeneous network, the route establishment based on simple battery status is not an effective strategy, because a node with multiple interfaces can broadcast multiple messages into the network by which the energy will get depleted.

Next, the method proposed by Tie T et al. [37] proposed an “Alternate link maximum energy level ad hoc distance vector scheme for energy-efficient ad hoc networks routing (ALMEL-AODV)”. In this approach, a final route is discovered based on the residual energy levels of nodes and the route with maximum energy is selected. A node capability is declared by comparing its residual energy level with a predefined threshold. At every node, the status of residual energy is buffered into the RREQ packet until it reaches to destination. If route failure occurs, then an error packet is sent to the source node, then it chooses an alternative route if it exists otherwise initiates the route discovery process. Nevertheless, this approach was obtained a limited performance in the small scale network due to the node mobility.

Further, a maximum transmission range based routing approach is proposed by Lalitha and Rajesh [38] based on the AODV protocol to minimize the overall energy consumption and also the transmission power. This approach is termed as AODV range routing (AODV-RR). In this approach, only a few nodes are selected to process the receiving and processing requests based on a new metric called as received signal strength (RSS). However, there is a need for further investigation about the selection of nodes which takes the responsibility of packets processing.

Mohamed A. Ryan et al. [42] proposed a new routing approach based on the energy and distance aware AODV (EDA-AODV) to reduce the routing overhead, prolong the lifetime and also to reduce the hop counts. In this approach, the route is selected based on two different metrics such as transmitting distance between the node and its predecessor node and the energy factor. However, this approach not considered the mobility by which the distance can be increased and the node already selected will move far

away which results in a longer path followed by more energy consumption.

M. R. Bosunia et al. [43] proposed a new routing protocol named “Energy-Aware and Error Resilient based on AODV (EAER-AODV)” in which the intermediate nodes selection is accomplished based on the forwarding capability. EAER metric derived as a combination of successful packet transfer probability and residual energy is measured for every node to measure this capability. However, the EAER metric only considered the transmission energy and reception energy which are not sufficient to define the packet forwarding capability of a node.

D Bhattacharya et al. [44] proposed a new routing approach by modifying the conventional AODV protocol to obtain reduced energy consumption by altering the size of the packet. This approach selects the best route based on a new metric, ‘Energy/Distance’ ratio. However, they didn’t show any interest in the mobility of nodes which has a significant effect on energy consumption as well as distance.

V. S. Devi and N. P Hegde [45] proposed a Power-Efficient Reliable Routing (PERR) based on AODV. This approach measures the power reliability metric (PRM) to measure the capability of a node to further forward the data.

The PRM is obtained by combining the reliability and remaining energy of the node. Here the reliability is measured with respect to the capability of successful packet transfer. The main advantage of this approach is the consideration of reliability and due to this packet delivery ratio is increased. However, for every packet transmission, checking the capability of a node results in an increased delay.

A “Multipath and Energy-Aware On-Demand Source Routing (MEA-DSR)” mechanism is proposed by Chettinad and Benmohammed [70] which finds the multiple disjoint paths for a given source and destination node pair, In this approach, the primary path s established based on two metrics and they are the total amount of power required for transmitting the data over the route and the residual energies of nodes on the route. Further, one more factor is also considered, i.e., the total number of hops and the route which have less in number are only selected. The authors demonstrated that this approach has gained significant performance in the high mobility scenarios but the packet delivery ratio is observed as low in the case of low mobility scenarios.

**Table.3 comparison of Reactive single metric based routing approaches**

Reference	Routing protocol	Metric	Advantages	Disadvantages
Ren P et al. [33]	ESAODV	Residual Energy of network and also the node	Better saving of energy at a non-participating node and also an increased delivery rate	not suitable for heavy traffic loads
Tarique and Tepe [34]	MEDSR & HMEDSR	Minimum Energy consumption through the modification of control packets	Reduced energy consumption at packet level hence total transmission power is less.	Inaccurate information due to the modification of control packets

Safa H et al. [36]	PHAODV	Energy cost and residual energy	Less energy consumption even for the node with multiple interfaces	Increased Flooding due to the heterogeneous nature of nodes
Tie T et al. [37]	ALL-AODV	Maximum energy for route and residual energy for node selection	Provides an additional high energy route in the case of route failures	Not effective for a network with lower node density
Lalitha and Rajesh [38]	AODV-RR	Received signal strength	Less communication overhead due to the non-participation of all nodes	Dynamic transmission power estimation is not supported
Mohamed A. Ryan et al. [42]	EDA-AODV	Energy Factor derived based on the transmission distance between nodes	Always gives the shortest path with reduced energy consumption	Increased route failures due to the non-consideration of mobility under distance evaluation
M. R. Bosunia et al. [43]	EAER-AODV	successful packet transfer capability based on remaining energy	Saves much energy due to the awareness of packet transfer capability	Only transmission and reception energy can't define the capability
D. Bhattacharya et al. [44]	Modified AODV	Energy/Distance ratio	Traces the best route with minimum energy/distance ratio for shorter range	Mobility introduces nodes movement too far distances, not discussed
V. S. Devi et al. [45]	PERR-AODV	Power Reliability Metric (PRM)	Reduced energy consumption with the highest packet delivery and fastest route recovery due to support nodes (SNs)	Packet size and packet type are not considered in the PRM evaluation and also increased the delay

### 3.2 Multiple metrics

In this category, the routing establishment process is done based on multiple metrics like energy, bandwidth, stability, mobility, etc. Both for MPR selection and for the route selection, this process checks the feasibility through multiple metrics. The methods described under this survey belong to both reactive and proactive protocols. Table.4 and table.5 gives the details of comparative analysis for proactive and reactive based routing approaches.

#### 3.2.1 Proactive Based Approaches

Joshi and Rege [46] proposed a multipath source routing approach based on the modification of the standard OLSR protocol, called as OLSRM. This method considered two different metrics such as the node's residual energy and drain rate during the selection of MPR. The multipath routing is done based on the min-max lifetime (MML) of links. Due to the consideration of multiple paths between source and destination nodes, this approach handled a perfect traffic load balancing and also the energy consumption. Along with residual energy, this approach also considered some more energy-related metrics during the selection of MPR.

Considering the composition of both residual energy and the power consumed at every node, new energy-efficient OLSR protocol is proposed Guo et al. [47], called as OLSR with Energy Awareness (OLSR-EA). They utilized the "Auto-regressive integrated moving average time series" technique to calculate the energy consumption at regular intervals. Based on this composite energy metric, the routing decisions are accomplished to select an energy effective route. Due to the consideration of both the residual

energy and power consumption at every node, this approach can better extend the network lifetime compared to the standard OLSR. However, this approach tried to select the MRPs based on the energy availability but generally, the MRPs are selected based on the coverage. Furthermore, this approach is not suitable for large scale networks.

Considering three different metrics such as energy, stability, and the occupancy of a buffer, a new MPR selection mechanism is proposed by Kots and Kumar [48], called QMPR. QMPR used fuzzy logic in the selection of MRPs. The main aim of this approach is to improve the quality in the selection of MRPs, i.e., the node which has higher energy, higher stability is only selected as final MPR and to do this, the fuzzy logic rules are applied. Though this method gained a qualitative MPR, the obtained path is always the shortest path that is not effective in all cases.

Anuradha, M., & Anandha Mala [49] considered three different metrics such as Residual Energy, Expected Transmission Time (ETT) and load-balancing factor and proposed a new integrated framework for route computation. Based on three metrics, a new metric is formulated, called as multi-objective cross-layer metric and integrated into the Multi-Path OLSR (MP-OLSR) [50] to get an effective route. The ETT metric is measured from the packet loss rate and the load balancing factor is obtained from the MAC layer. However, due to the accomplishment of the same MPR mechanism, used in MP-OLSR, there is a chance of over packet flooding; hence the drain rate of a node will be increased.

Sarkar et al. [51] proposed a new route selection mechanism, called Mobility Aware Routing (MAR) based on the mobility factor which is derived by combining speed, pause time and the direction of movement. This approach can effectively analyze the topology changes both in the dynamic and static scenarios, due to the node movement in random directions. This approach has gained better QoS; however, the computational time required to analyze the direction of node movement is too high which introduces an unnecessary delay.

To attain a stable link, Ladas et al. [52] proposed a Multipath Chameleon (M-CML) routing which utilizes three QoS metrics and provided the results with statistical confidence interval by applying the *Wilcoxon signed-rank test* [53] model. This approach has attained a less routing overhead and also the less energy consumption by reducing the total number of duplicate packets generation. However, in a dynamic network, the link quality has a serious impact, results in a heavier route failure rate.

Li and Wu [54] proposed a new Smooth Mobility and Mink Reliability-based OLSR (SMLR-OLSR) routing

mechanism for MANETs. This approach is implemented on the basis of semi-markov smooth and complex restricted mobility model which have a realistic node behavior. The combination of these two metrics is used in the selection of MPRs. Though this approach has obtained a less overhead, the complex restricted mobility is not applicable for real-time scenarios.

De rango et al. [55] proposed a Link Stability and Energy-Aware Routing protocol (LAER) to perform a scalable routing in MANETs. This approach combines two metrics such as energy drain rate and link stability. To obtain an optimal route this approach accomplished Bi-objective Integer Programming [56] model. The BIP model selects the next-hop node which has less energy consumption towards the destination and also has higher stability. The main advantages of LAER are the provision of robustness and also an improved network lifetime. However, the link stability is mainly dependent on the node mobility which is not considered during the MPR selection.

**Table.4 comparison of Proactive Multiple metric-based routing approaches**

Reference	Routing protocol	Metric	Advantages	Disadvantages
Joshi and Rege [46]	OLSRM	Drain rate and residual energy	Discovers multiple paths with balanced energy levels at every node through MML	Not concentrated on the mobility through which the stability of network disturbs
Guo et al. [47]	OLSR-EA	Residual energy and transmission energy	Per interval-based prediction results in more effective paths and nodes	Per interval, prediction ensures a longer delays
Kots and Kumar [48]	QMPR	energy, stability, and the occupancy of the buffer	qualitative MPR selection	Always obtains the shortest path which is not efficient in all cases.
Anuradha, M., & Anandha Mala [49]	MP-OLSR	Residual Energy, ETT and load-balancing factor	Reliable, load balancing, and energy-efficient routing	over packet flooding
Sarkar et al. [51]	MAR	Mobility factor based on speed, pause time and direction	Better QoS	Longer delay in the evaluation of the direction of node movement
Ladas et al. [52]	M-CML	Three QoS metrics	Reduced duplicate packets generation	Heavier route failure rate due to link quality

### 3.2.2 Reactive Based Approaches

Kadri et al. [57] proposed a Weight Based DSR (WBDSR) that considers the weight of a node as a reference metric during the selection of a forwarding node. In this approach, the weigh is derived from two metrics such as stability and Battery level of the node. The final nod and path are selected for a node/path which has maximum weight. For two routes with the same weight, the minimum hop number route is selected as a final route. Nevertheless, the network size variations have much effect on this scheme because the size directly affects stability. Li L, and Li C [58] proposed an energy level based routing protocol (ELBRP) based on AODV to reduce energy consumption

and also the delay. To achieve these metrics, ELBRP considered two metrics such as the Energy level of node and delay. Based on the level of energy, the nodes are classified into four classes such as safety, sub safety, danger, and every danger. Furthermore, based on the present state, the nodes are classified as dead, sleeping, listening, receiving and transmitting. However, this approach is simulated over a few scenarios and also not considered the impact of other parameters such as traffic load and the size of the network. Bhatt et al. [59] proposed a modified version of DSR, DSR1 by modifying the process of a route to discover at the intermediate nodes.

This approach considered three parameters such as received signal strength, residual energy, and node speed to reduce the congestion followed by energy consumption in the MANETs. However, the delay of DSR 1 is observed to be high compared to the DSR, because, the route discovery process of DSR1 consumes more time due to the consideration of multiple parameters. Furthermore, this approach is not much suitable for small scale networks.

A similar approach is proposed by Varaprasad and Narayanagowda [60], EDSR, based on the DSR protocol. This approach focused to improve the network lifetime by reducing energy consumption at the time of route selection. This approach considered two metrics such as Energy cost per packet and lifetime to find the selfish intermediate nodes at which the packet may get drop and these nodes try to save their batteries. EDSR attained reduced power consumption and increased lifetime but the time delay is increased due to the modified route discovery process. To overcome this problem, the same authors proposed another routing mechanism, called Efficient Power-Aware Routing based on DSR (EPRDSR) [61] which considered the power and bandwidth parameters during the selection of the route. In this approach, the final route is selected as the one which has a minimum number of hops and maximum available power. Though the packet delivery rate is observed as high for EPRDSR compared to DER, the end-to-end delay is high due to the discovery of alternative paths.

Dhurandher et al. [62] proposed an energy-efficient AODV based routing (EEAODR) to prevent the nodes from exhausting. This approach considered three parameters such as a number of hops, time and energy levels of nodes during the route selection. Furthermore, this approach also observes the constraints those consequences to node depletion like the size of a packet, type of packet, node energy, and the distance between nodes in making the decision regarding the route selection. In the case of equal energies of all nodes and also the paths, the shortest path is only selected which is not a feasible solution for all types of networks.

Katiravan et al. [63] developed an “Energy Efficient and Link-Quality Aware Routing Approach with Variable Power Control (ELRPP)” in which the route selection is done based on three different metrics such as Link Quality, Signal to Noise Ratio (SNR), and residual energy. In this approach, the transmission power is controlled by making the nodes clustered. The link quality metric measures the conditions of the channel with respect to fading and mobility effects. The consideration of transmission power along with multiple metrics for route selection has resulted in an effective performance. However,

this approach results in a longer delay for the network with larger node density due to the processes multi-metric based route selection.

One new method, Minimum Spanning Tree (MST) [67] based power-aware routing is proposed by Yanez-Marquez et al. [64], based on the network topology. This approach constructed with the help of MST combined with binary decision diagrams (BDDs) [65]. This approach is a modified version of the conventional Power-Aware Route optimization (PARO) approach [66]. In the derivation of MST, this method searches for a node with lesser distance to its per-hop node and the power required id directly proportional to the distance between the nodes. Though this approach is simple, it is not effective for networks with larger node density. Along with this problem, the node with high mobility ensures increased route failures.

Rishwal et al. [68] proposed a Power-Aware Routing (PAR) to reduce the congestion followed by energy consumption.

This approach considered three metrics to control the power ad congestion of a route, they are data type ready to transfer, battery lifetime status and the accumulated energy of path. The simulation results demonstrated that the obtained network lifetime and average energy consumption are more effective for PAR compared to the conventional DSR and AODV. However, the PAR experiences longer delays in the case of multimedia data which has larger sizes.

A “Multi-constrained and Multipath QoS aware routing protocol (MMQARP)” is proposed by Balachandra et al. [69] which considers multiple constraints in the route computation and also discovers multiple paths at a single instant of the route discovery phase. The obtained multiple paths are nods-disjoint and on-demand in nature. This approach considered three metrics for route computations. They are battery power, delay across the links and route reliability obtained through the node position and movement. This approach obtained energy efficient, reliable and delay aware paths. Nevertheless, this approach doesn't perform well for the network with low mobility.

Gudong et al. [71] proposed energy-efficient and load balancing geographic routing (ELGR) to improve the network lifetime and also the packet delivery ratio. This approach considered two metrics such as energy efficiency and load balancing and based on these two metrics, one weight is assigned to every hop. The load balancing metric is derived from a packet reception rate (PRR). The main drawback of this approach is the increased computational complexity due to the measurement of PRR, weight and forwarding rate.

**Table.5 comparison of Reactive Multiple metric-based routing approaches**

Reference	Routing protocol	Metric	Advantages	Disadvantages
Kadri et al. [57]	WBDSR	Weight metric based on stability and energy	Fewer link failures	Not effective for a network with less node number
Li L, and Li C, [58]	ELBRP	Delay and energy level of a node	Less delay, balanced energy consumption, and complex free algorithm	Not simulated under varying traffic load and the size of the network

Bhatt et al. [59]	DSR1	received signal strength, residual energy, and node speed	Congestion in control and less energy consumption	More time-consuming at the route discovery phase
Varaprasad and Narayanagowda [60]	DSR	Energy cost per packet and lifetime	reduced power consumption and increased lifetime	time delay is increased due to the modified route discovery process
Shankar, S., Varaprasad [61]	EPRDSR	Bandwidth and power	Congestion control due to the bandwidth consideration	High end-to-end delay
Dhurandher et al. [62]	EEAODR	number of hops, time, size of a packet, type of packet, node energy, and the distance between nodes	Higher packet delivery ratio and less delay	High Computational complexity
Katiravan et al. [63]	ELRPP	Link Quality, Signal to Noise Ratio (SNR), and residual energy	Controlled transmission power due to the node clustering	a longer delay for the network with a larger number of nodes
Balachandra et al. [69]	MMQARP	battery power, delay across the links and route reliability	Paths are energy efficient, reliable and delay aware	Not effective for multimedia data transmission

### 3.3 Learning-based routing approaches

Under this scenario, the routing process is done in the presence of artificial intelligence. An objective function is defined through multiple metrics and it is optimized in an iterative fashion. At every phase, current output depends on the earlier input. Routing based on metaheuristic algorithms like a genetic algorithm (GA) [72, 73], Particle swarm optimization (PSO) [74], and ant colony optimization (ACO) [75, 76] are some of the examples for this kind of routing.

Y. S Yen et al. [72] discussed the multicast routing problem with multiple QoS constraints in MANETs. This approach proposed an energy-efficient GA mechanism to solve these problems. Further, to minimize the delay time through a small population in the GA, the shortest tree-based routing algorithm and discovers the shortest path. This approach has gained better results in the multi-cast problem. Next, Kaliappan M et al. [73] used GA to optimize the “Dynamic Load Balanced Clustering Problem (DLBCP)”. Since the reliable data transfer and load balancing are more important to extend the lifetime of a MANETs, this approach used a dynamic genetic algorithm such as “Elitism based immigrants Genetic Algorithm (EIGA)” and “Memory enhanced Genetic Algorithm (MEGA)” to solve the DLBCP. In this approach, the optimal cluster head is selected based on the energy and distance metrics. Though this approach gained a promising performance in the improvisation of delivery rate, this approach not focused on the mobility of nodes which has a significant effect on the stability of the network.

S Jamali et al. [74] employed Binary PSO (BPSO) with the TORA routing protocol to create awareness about the energy for every node in the MANET. This approach considered the length of the route and their energy levels in the route selection. This approach formulates the routing issue as an optimization problem and then applies BPSO to solve it and to select a rough with optimal weight function in regard to route length and energy level of the route.

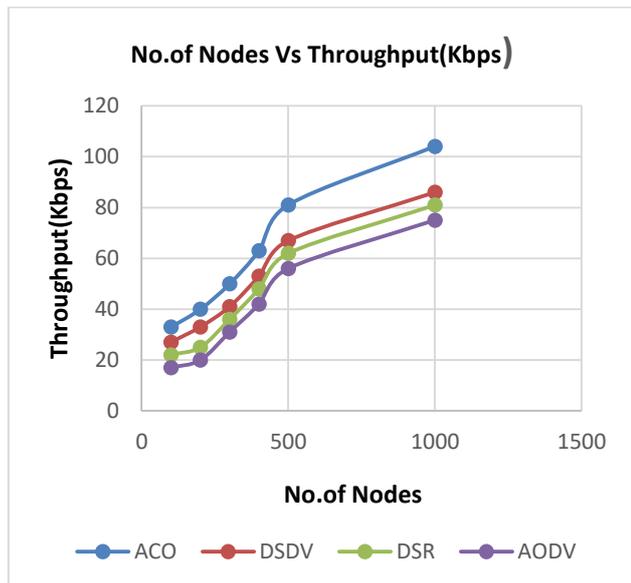
To improve the QoS in MANETs, Dipika Sarkar et al. [75] proposed a new routing mechanism by combining the ACO with AODV protocol. In this approach, the final route is selected based on the pheromone value of path and the pheromone is derived based on the three metrics such as residual energy of nodes, number of hops and congestion. The path is selected based on the larger pheromone value.

Based on the ACO algorithm, Zhou et al. [76] proposed the “Ant-Colony Based Energy Control Routing (ACECR)” to discover an optimal route with the help of a positive feedback character. Along with a number of hops and the node energy, this approach also considered the minimum and average energy of routes during the route selection.

A.Nagaraju et al. [77-80] proposed Rough Set and Weighted Rough Set Based AODV and DSR techniques to improve the performance of reactive routing protocols. The proposed protocol uses Rough and Weighted Rough mathematical models to reactive routing protocols to optimize the redundant broadcasting in broadcast nature of Wireless Mobile Ad-Hoc Networks.

## IV. RESULTS AND DISCUSSION

As shown in figure.3, various routing algorithms taken and Throughput is calculated and compared with various algorithms of ACO,DSR, AODV, and DSDV in without attacking mode.



**Figure .3 Throughput Comparison between various Routing Algorithms**

## V. CONCLUSION

In this paper, a detailed survey is carried out over the routing approaches of MANETs. Since the nodes in MANET are resource-constrained in nature, to obtain a prolonged life with effective node utilization, the route established for any source and destination node pair must be more effective. Towards such objective, various approaches are developed earlier and they are classified as single metric-based approaches and multiple metric-based approaches. The further classification is done based on the accomplished protocol such as reactive or proactive or hybrid. Further, some more approaches are used the meta-heuristic algorithms for the route computation and the details are also stipulated. Detailed analysis and comparison are also shown in this paper with respect to various constraints such as metrics, advantages, and disadvantages.

## REFERENCES

1. M Bansal, R Rajput, & G Gupta,1999, "Mobile ad hoc networking (MANET): Routing protocol performance issues and evaluation considerations" .
2. I Chlamtac, M Conti,and, Liu, J, 2003, "Mobile ad hoc networking: Imperatives and challenges". Ad Hoc Networks, 1(1), 13–64.
3. K Gorantala 2006, "Routing protocols in mobile Adhoc Networks".
4. M Conti, & S Giordano, 2007, "Multihop Adhoc networking: The theory"pp, 78–86.
5. L Cao, T Dahlberg,& Y Wang,2007 "Performance evaluation of energy-efficient ad hoc routing protocols". In IEEE International on Performance, Computing, and Communications Conference, 2007. IPCCC 2007 (pp. 306–313).
6. N Vassileva, F Barcelo-Arroyo, 2008, "A survey of routing protocols for maximizing the lifetime of ad hoc wireless networks"pp, 77–90.
7. Thomas Kunz ,2008, "Accurately Predicting Residual Energy Levels in MANETs". IEEE International Conference on Wireless and Mobile Computing, Networking, and Communications, Avignon, France.
8. Martin Appiah ,2017, "Performance comparison of mobility models in Mobile Ad Hoc Network (MANET)".
9. Bhavyesh Divecha, Ajith Abraham, Crina Grosan, Sugata Sanyal, 2007, "Impact of Node Mobility on MANET Routing Protocols Models", Journal of Digital Information Management. 5(1).
10. Wen Chen Ching- and Chi Weng Chuan, 2009, "Bandwidth based routing protocols in mobile Adhoc networks". The journal of supercomputing. 50:240.

11. Parkash, A Surjeet, and R Tripathi,2013, "QoS Bandwidth Estimation Scheme for Delay Sensitive Applications in MANETs". Journal of Communications and Network, 5, 1-8.
12. C.E. Perkins and P. Bhagwat, 1994, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers", Comp. Comm. Rev., pp.234-244.
13. Park VD and MS Corson ,1997, "A highly adaptive distributed routing algorithm for mobile wireless networks", Proc. INFOCOM'97, 9 pages.
14. B David. Johnson, A Davis. Maltz, 1999, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks" October 1999 IETF Draft, 49 pages.
15. E Charles. Perkins, M Elizabeth. Royer, R Samir, 1999, "Ad Hoc On-demand Distance Vector Routing, October 99 IETF Draft, 33 pages.
16. Murthy S. and Garcia J,Luna-Aceves, 1996, "An Efficient Routing Protocol for Wireless Networks", pp. 183-97.
17. M Joa-Ng and I-T. Lu,1999, "A Peer-to-Peer zone-based two-level link-state routing for mobile Ad Hoc Networks", pp.1415-25.
18. Chiang C. C, 1997, "Routing in Clustered Multihop, Mobile Wireless Networks with Fading Channel". Proc. IEEE SICON'97, pp.197-211.
19. Bellur B, and Ogier R.G, 1999, "A Reliable, Efficient Topology Broadcast Protocol for Dynamic Networks," Proc. IEEE INFOCOMM '99, pp. 178–186.
20. Jacquet P, Muhlethaler P, 2001," Optimized link-state routing protocol for ad hoc networks". In Proceedings of IEEE International Multi-Topic Conference, IEEE INMIC 2001.
21. Ali Moussaoui, Semchedine Fouzi, 2014, "A link-state QoS routing protocol based on link stability for Mobile Ad hoc Networks",pp.117–125.
22. Billington J. and C Yuan, "On modeling and analyzing the dynamic MANET on-demand (DYMO) routing protocol, 2009, pp. 98–126.
23. Z Haas, J, Pearlman, M. R., and Samar, P., (2002). "The Zone Routing Protocol (ZRP) for Ad Hoc Networks". IETF internet-draft.
24. Maciej Wojciechowski, 2008, "Border Gateway Protocol Modeling and Simulation".
25. Lammle, 2007, "CCNA Cisco Certified Network Associate Study Guide (Sixth ed)", Indianapolis, Indiana: Wiley Publishing, ISBN 978-0-470-11008-9.
26. N Ghanem, S Boumerdassi, & E Renault, 2005, "New energy-saving mechanisms for mobile ad-hoc networks using OLSR". pp. 273–274.
27. Rango De, Fotino F, M, & S Marano, 2008, "EE-OLSR: Energy efficient OLSR routing protocol for mobile ad-hoc networks". In IEEE (pp. 1–7).
28. L Fatima, & E Najib, 2012, "Energy and mobility in the OLSR routing protocol", Journal of Selected Areas in Telecommunications (JSAT), 2012(3), 1–6.
29. T Kunz, & R Alhalimi, 2010, "Energy-efficient proactive routing in MANET: Energy metrics accuracy. Ad Hoc Networks", 8(7), pp.755–766.
30. A Benslimane, Khoury El, R, Azouzi El, R, & S Pierre, 2006, "Energy power-aware routing in OLSR protocol",MCWC 2006 (pp. 14–19). IEEE.
31. S Mahfoudh , & P Minet, 2008, "An energy efficient routing based on OLSR in wireless ad hoc and sensor networks",AINAW 2008 (pp. 1253–1259). IEEE.
32. T Kunz,2008, "Energy-efficient variations of OLSR. In Wireless Communications and Mobile Computing Conference", IWCMC'08 International (pp. 517–522). IEEE.
33. P Ren, J Feng, P Hu, & J Cai, 2009, "Energy saving ad-hoc on-demand distance vector routing for mobile ad-hoc networks". In IEEE International Conference on Communications, 2009. ICC'09 (pp. 1–5). IEEE.
34. M Tarique, & K. E Tepe, 2009," Minimum energy hierarchical dynamic source routing for mobile ad hoc networks" , 7(6),pp.1125–1135.
35. M Tarique, & K. E Tepe, 2007, "A new hierarchical approach to reactive routing protocols for wireless ad hoc networks with cross-layer design", 2(1), pp. 12–20.
36. H Safa, M Karam, & B Moussa, 2014, "PHAODV: Power aware heterogeneous routing protocol for MANETs",pp. 60–71.
37. Tie, T. H., Tan, C. E., & Lau, S. P. (2010). "Alternate link maximum energy level ad hoc distance vector scheme for energy efficient ad hoc networks routing". In 2010 International Conference on Computer and Communication Engineering (ICCCCE) (pp. 1–6). IEEE.
38. Lalitha, V., & Rajesh, R. S. (2014). "AODV\_RR: A maximum transmission range based ad hoc on-demand distance vector routing in MANET". Wireless Personal Communications, 78(1), 491–506.

39. Waheb A. Jabbar, Mahamod Ismail, and Rosdiadee Nordin. (2014). "Performance Evaluation of the MBA-OLSR Routing Protocol for MANETs". *Journal of Computer Networks and Communications* Volume 2014, Article ID 951638, 10 pages.
40. T. Clausen, C. Dearlove, and P. Jacquet, "The optimized link-state routing protocol version 2," draft-IETF-manet-olsrv2-00, Work in progress, 2006.
41. M. A. Adhoc Networking and U. Herberg, "Integrity Check Value and Timestamp TLV Definitions for Mobile Ad Hoc Networks (MANETs) draft-ietf-manet-rfc6622-bis-03," 2013.
42. Mohamed A. Ryan, Sayed Nouh, Tarek M. Salem, Abdelhady M. Naguib. (2018). "EDA-AODV: Energy and Distance Aware AODV Routing Protocol". Volume 5, Issue 5, September – October (2018).
43. Rahman Mahfuzur Bosunia, Daniel P, and Seong-Ho Jeong, 2015, "A New Routing Protocol with High Energy Efficiency and Reliability for Data Delivery in Mobile Ad Hoc Networks", 8 pages.
44. Debika Bhattacharyya, Avimita Chatterjee, Baisakhi Chatterjee, Arnab Kumar Saha, Arnab Santra. (2018). "A novel approach to energy-efficient low-cost routing in MANET by a reduction in packet size". *IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, Las Vegas, NV, USA.
45. S. Devi, and N. P Hegde, (2016). "Reliable and Power Efficient Routing Protocol for MANETs". *I. J. Computer Network and Information Security*, 2016, 10, 61-69.
46. Joshi, R. D., & Rege, P. P. (2012). "Implementation and analytical modeling of modified optimized link-state routing protocol for network lifetime improvement". *IET Communications*, 6(10), 1270–1277
47. Guo, Z., Malakooti, S., Sheikh, S., Al-Najjar, C., Lehman, M., & Malakooti, B. (2011). "Energy-aware proactive optimized link-state routing in mobile ad-hoc networks". *Applied Mathematical Modelling*, 35(10), 4715–4729.
48. Kots, A., & Kumar, M, 2014, "The fuzzy-based QMPR selection for OLSR routing protocol". *Wireless Networks*, 20(1), 1–10.
49. Anuradha, M., & Anandha Mala, G. S. 2014. "Multi-objective cross-layer based multipath routing protocol in MANET", 68(3), page no. 531–540.
50. Yi, J., Cizeron, E., Hamma, S., & Parrein, B. (2008). "Simulation and performance analysis of MP-OLSR for mobile ad hoc networks", pp. 2235–2240.
51. S Sarkar, R Datta, "Mobility-aware route selection technique for mobile ad hoc networks". *IET Wirel. Sens. Syst.* 2017, 7, 55–64.
52. Ladas, A.; Deepak, G.C.; Pavlatos, N.; Politis, C. "A selective multipath routing protocol for ubiquitous networks". *Ad Hoc Netw.* 2018, 77, 95–107.
53. Derrick, B; White, P (2017). "Comparing Two Samples from an Individual Likert Question". *International Journal of Mathematics and Statistics.* 18 (3): 1–13.
54. Li, Z.; Wu, Y. "Smooth mobility and link reliability-based optimized link state routing scheme for MANETS". *IEEE Commun. Lett.* 2017, 21, 1529–1532.
55. De Rango, F.; Guerriero, F.; Fazio, P. "Link-stability and energy-aware routing protocol in distributed wireless networks". *IEEE Trans. Parallel Distrib. Syst.* 2012, 23, 713–726.
56. Ehr Gott, Matthias, Xavier Gandibleux. 2006. "Bound sets for bi-objective combinatorial optimization problems". *Computers & Operations Research*, 34 2674–2694
57. Kadri, B., Feham, M., & M' Hamed, A. (2008), "Weight-based DSR for mobile ad hoc networks". In *IEEE* (pp. 1–6).
58. Li, L., Li, C., & Yuan, P. (2015), "An energy level-based routing protocol in ad hoc networks". *Wireless Personal Communications*, 81(3), 981–996.
59. Bhatt, U. R., Nema, N., & Upadhyay, R. (2014). "Enhanced DSR: An efficient routing protocol for MANET". pp.215–219.
60. G Varaprasad, & Narayanagowda, S. H, 2013, "Implementing a new power-aware routing algorithm based on an existing dynamic source routing protocol for mobile ad hoc networks", pp.137–142.
61. S Shankar, G Varaprasad, & H. N Suresh, 2014, "Importance of on-demand modified power-aware dynamic source routing protocol in mobile ad-hoc networks". *IET on Microwaves, Antennas & Propagation*, 8(7), 459–464.
62. K., Misra, Dhurandher, S, S M Obaidat, S, Bansal, & Punia, V. 2009, "EEAODR: An energy-efficient ad hoc on-demand routing protocol for mobile ad hoc networks". *International Journal of Communication Systems*, 22(7), 789–817.
63. Katiravan, J., Sylvia, D., & Rao, D. S. (2015). Energy-efficient link aware routing with power control in wireless ad hoc networks. *The Scientific World Journal*.
64. Yanez-Marquez, C., I Lopez-Yanez, O Camacho-Nieto, 2013, "BDD-based algorithm for the minimum spanning tree in wireless ad-hoc network routing", pp.600–601.
65. B Bollig, 2012, "On symbolic OBDD-based algorithms for the minimum spanning tree problem". *Theoretical Computer Science*, 447, pp. 2–12.
66. Gomez, J., Campbell, A. T., Naghshineh, M., & Bisdikian, C. (2003). "PARO: Supporting dynamic power-controlled routing in wireless ad hoc networks". *Wireless Networks*, 9(5), 443–460.
67. Y. P. Aneja, A. Bari, A. Jaekel. (2009). "Minimum Energy Strong Bidirectional Topology for Ad Hoc Wireless Sensor Networks". *IEEE ICC 2009*.
68. Rishiwal, V., Yadav, M., Bajapai, S., & Verma, S. (2009), "Power-aware routing in ad hoc wireless networks". *Journal of Computer Science and Technology*, 9(2), 101–109.
69. Balachandra, M., Prema, K., & Makkithaya, K. (2014), "Multi-constrained and multipath QoS aware routing protocol for MANETs". *Wireless Networks*, 20(8), 2395–2408.
70. Chettibi, S., & Benmohamed, M. (2009), "Multipath energy-aware on-demand source routing protocol for mobile ad-hoc networks".
71. Guodong, W., Gang, W., & Jun, Z. (2010), "ELGR: An energy efficiency and load-balanced geographic routing algorithm for lossy mobile ad hoc networks", pp.334–340.
72. Sheng Yen Yun, Chan Yi-Kung, Han Chieh Chao, Jong Hyuk Park, (2008) "A genetic algorithm for energy-efficient based multicast routing on MANETs". *Computer Communications* 31 (2008) 2632–2641.
73. SusanAugustine, IM.Kaliappan, Paramasivan B, 2016, "Enhancing energy efficiency and load balancing in mobile ad hoc networks using dynamic genetic algorithms", Volume 73, September 2016, Pages 35-43.
74. ShahramJamali, LeilaRezaei, Sajjad JahanbakhshGudakahriz, (2013). An Energy-efficient Routing Protocol for MANETs: a Particle Swarm Optimization Approach. *Journal of applied research and technology.* Volume 11, Issue 6, December 2013, Pages 803-812.
75. DipikaSarkar, AbhishekMajumder, SwagataChoudhury, 2018, "Enhanced-Ant-AODV for optimal route selection in a mobile ad-hoc network", 2018.
76. Zhou, J., Tan, H, 2016, "Ant colony-based energy control routing protocol for mobile ad hoc networks under different node mobility models". *EURASIP J. Wirel. Commun. Networking*, 2016:105.
77. A.Nagaraju, S.Ramachandram, (2014). "Mathematical Models to Reduce Redundant Broadcasting in MANETs," *International Journal of Wireless and Mobile Communication (IJWMC)*
78. A.Nagaraju, S Ramachandram, "A Strategy to Reduce the Control Packet Load of AODV Using Weighted Rough Set Model For MANET," *International Journal of Arab Information Technology (IAJIT)*, Vol.8, No.1
79. A.Nagaraju, S Ramachandram, "A Strategy to Reduce the Control Packet Load of AODV Using Weighted Rough Set Model For MANET," *International Journal of Arab Information Technology (IAJIT)*, Vol.8, No.1.
80. A.Nagaraju, S.Ramachandram,(2009) "Rough Set based Ad-hoc On-demand Distance vector Routing algorithm for MANET's," *Proceedings of International Conference On Compute-2009 ACM Bangalore Chapter*. Paper is available in ACM Portal.