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MULTIPATH ROUTING IN MOBILE MULTIHOP AD HOC NETWORKS – A SYSTEMATIC LITERATURE REVIEW

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Abstract
With the drastic emergence of wireless communication technology, Mobile Multihop Ad Hoc Networks have extended its reach in many real-world applications. In terms of reliability and performance in such networks, routing protocols plays major role. Routing protocols present in Mobile Multihop Ad Hoc Networks can be classified by using a number of parameters and one of the important parameter is number of paths or routes present in between source node and destination node. And classification types based on parameter number of paths are unipath routing protocols and multipath routing protocols. The present paper therefore has conducted a systematic literature review on multipath routing mechanism for Mobile Ad-hoc Network. The paper also focused on some of the multipath routing protocols based on the concept of meta-heuristic approach. Paper discussed the methodology, features and limitations of existing multipath routing protocols. Paper also discussed some findings , future scope by considering the existing research related to this field.

Keywords: Mobile Ad hoc Network, MANET, multipath routing, meta-heuristic.

I. INTRODUCTION

Mobile Multi hop Ad hoc Network - MANET :

Wireless connectivity broadly classified into two classes. The first approach is infrastructure based wireless network, and the second approach is infrastructure less wireless network. Wireless network which form through infrastructure make the use of access points(AP) or base station(BS) for connection between wired and wireless network or to extend the coverage of wireless network. Access point helps the wireless node to connect existing wired networks. Wireless network present at airports, hospitals, offices, homes etc. where the end user connects with the Internet with the help of access points are some common examples of Infrastructure based wireless network [6,1]. Figure 1 shows a wireless network based on infrastructure. The second category of wireless networks, which is commonly known as ad hoc wireless network does not have fixed infrastructure. This kind of network is also called as “on the fly network” . When the nodes present in such a network can change their positions any time, anywhere, it will become a Mobile Ad hoc Network.

Figure -1

Figure -2

These types of network do not need wireless access point to form the connection between two devices. Ad hoc wireless connectivity is more applicable in the situations where infrastructure is not possible or infrastructure is damaged due to some disaster situations. These types of network is useful where infrastructure based communication is not possible due to environment aspect or cost aspect or where rapid deployment of communication is needed e.g emergency situation, conference meeting, military applications etc. Figure 2 shows a wireless network which does not have fixed infrastructure i.e ad hoc wireless network.

With the drastic emergence of wireless communication technology, Mobile Multihop Ad Hoc Networks have extended its reach in many real-world applications [2]. Applications of Mobile Multihop Ad Hoc Network are crucial in tactical battlefield operations, emergency rescue operations, commercial and civilian environments, smart cities, and mobile conferencing [3]. In general, in Multihop Ad hoc Network, mobile nodes is having self-governing system, which are linked with each other through wireless connections and having decentralized administration. Mobile Multihop Ad Hoc Networks popularly known as MANET which aim to achieve data transmission between nodes, hence the first and very basic assumption related to MANET is that an end-to-end connection exists from the source node to the destination node, possibly via multiple intermediate nodes. To form the communication between mobile nodes in such a dynamic topology network, protocols present for routing purposes should be efficient and reliable to determine new routes and to maintain the existing routes[4].

In terms of reliability, routing protocols play a major role in dramatically impacting the performance of the complete network in terms of energy consumption, delay and bandwidth utilization. Routing protocols present in Mobile Multihop Ad Hoc Networks can be classified by using a number of parameters and one of the important parameter is number of paths or routes present in between source node and destination node. And classification types based on parameter number of paths are unipath routing protocols and multipath routing protocols. The routing protocols which follows the unipath , delivers the data packets to the destination node from the source node using a single route. If the routing protocol is single path, it should get repaired every time when it breaks. The route repair process generates many control packets which leads to increase in end to end delay. To overcome the pitfalls of the routing protocols which follow the single path, the new technique – multipath routing has been proposed where packets are delivered through more than one route [5]. Multipath routing protocols scheme has many advantages over single path like, it improves the reliability of data transmission [6], minimizes the end to end delay, balance the load , increases the fault tolerance ratio, reduces the frequency of route enquiries and through all this it helps to lower the overall routing overhead. Another major challenge in Mobile Multihop Ad Hoc Network is performance optimization mainly during network management when it finds a path between the communication endpoints satisfying the QoS requirement of a user is a difficult task, specifically in a dynamic environment. The studies suggest that stochastic, nature-inspired algorithms or meta-heuristic algorithms are adopted in order to achieve an optimal routing path in Mobile Multihop Ad Hoc Networks [7,8].

The present paper therefore has conducted a systematic literature review on multipath routing mechanism for Mobile Ad-hoc Network. Authors of the paper started the survey by collecting papers on the topics routing protocols and routing methods used in MANET in literature. Present group selected around 200 scientific research articles published in the last 10 years using the keywords as Multipath routing , Mobile Ad hoc Network , Bio Inspired algorithm. While conducting the literature review the present group also considered the aspects like measurement parameters for the routing in Mobile Ad-hoc Network. Measurement parameters classed as Quality of Service(QOS), energy requirement etc

In-depth analysis filters 24 most significant works. While selecting the papers for the survey authors considered the number of citations , publication journal etc. parameters. Systematic literature survey of the topic took around one year to review the literature.

Rest of the paper is organised as follows. In section 2 present group summarizes the related work about multipath routing protocol focusing on its concept, methodology, features and limitations. section 3 discussed about challenges and issues and future scope related to multipath routing in multihop mobile ad hoc network and section 4 concludes the paper.

II. LITERATURE SURVEY

A. Multipath routing protocols in Multihop Mobile Ad-hoc Network:

Multipath routing protocols scheme has many advantages over single path like, it improves the reliability of data transmission [6], minimizes the end to end delay, balance the load , increases the fault tolerance ratio, reduces the frequency of route enquiries and through all this it helps to lower the overall routing overhead

If route fault is detected and route break down occurs then the process of route recovery is fast and dynamic in Multipath routing protocol. In a multipath routing mechanism more than one path is established from source to destination at the time of route discovery process. A source node in this technique has the ability to discover several routes between the sources to destination in one route discovery process.. Again the studies suggest that stochastic, nature-inspired algorithms or meta-heuristic algorithms are adopted in order to achieve an optimal routing path in Mobile Multihop Ad Hoc Networks. Hence this section provides the detailed description of various existing multipath routing protocols in Multihop Mobile Ad hoc Network including some nature inspired , stochastic , meta-heuristic algorithms . These protocols are described as follows.

B. Related Work

Multipath Battery and Mobility-Aware routing (MBMA-OLSR) is an energy and mobility conscious multipath routing scheme [17] and is introduced MP-OL SRv2 technique and selection mechanism of this scheme considers an Energy and Mobility Aware Multi-Point Relay (EMA-MPR). This hybrid routing mechanism combines mobility awareness and energy metrics by taking advantage of the multipath notion. This method chooses the most effective paths to convey data to the target, achieving balanced energy over various paths. Using the ant colony optimisation technique, a new multipath routing algorithm [18] is suggested for multimedia services that are QoS-sensitive. This protocol selects the most effective routes that adhere to the bandwidth and delay requirements of the QoS. Any type of traffic situation is suitable for this multipath routing

FF-AOMDV [19] is ad hoc on demand distance vector protocol version with the fitness function and multipath facility. This protocol mainly focuses on low energy consumption. The fitness function in FF-AOMDV employs as an optimization method, where the energy of route and route distance are two parameters considered for selecting the optimum route and prolonging the network lifetime. Mobility, Residual energy, and Link quality Aware Multipath (MRLAM) [20] aim to solve the drawbacks faced in existing multipath routing techniques. The technique which is used in MRLAM, selects intermediate nodes using Q-learning algorithm. The parameters like status of energy level, link quality and mobility of nodes used to choose the intermediate nodes by providing positive and negative reward values to them. In [21] load balancing is done through energy constraint and selects the nodes using parameters as interface queue length of MAC layer and residual energy. A node with minimum queue length of interface queue of MAC layer and uppermost residual energy is selected to forward the packet. If the queue length of node is lesser than threshold value then node respond to RREQ packets If the condition fails, then the RREQ packets are discarded automatically. Load Balancing Ad hoc On-demand Multipath Distance Vector (LBAOMDV) protocol [22] is an adaptation of AOMDV protocol that enhances the reliability of the network by considering the energy of all the available multiple paths. The LBAOMDV protocol aims to load balancing of data across all available paths. However, the scheme suffers from high computational inefficiency. The real-time routing algorithm in [23] adopts a Q-learning mechanism for updating values of the actions. It lessens the transmission time of packet by selecting the neighbor node having little transmission delay. This methodology provides a better packet delivery with efficient routing in Mobile Multihop Adhoc Network.

A multipath routing scheme of [24] prevents the flooding disruption attacks by optimizing the link state routing mechanism. During the discovery phase of network topology routing strategy computes MPR sets with additional coverage. The primary objective of this mechanism is to obtain a flexible method to discover multiple disjoint paths between any two nodes of a Mobile Multihop Adhoc Network. This multipath strategy provides better performance than its existing schemes but with the same multi disjoint paths. A novel bio-inspired routing protocol [25] integrated the concept of Cuckoo Search Algorithm with a metaheuristic approach in AODV routing protocol. The adopted metaheuristic mechanism

provides reduced time consumption and facilitates efficient routing. This approach is scalable and flexible due to the optimal selection of routing using the metaheuristic algorithm. An adaptive multipath routing based on the leapfrog algorithm [26] solves the problem of congestion during transmission in WSNs. This multipath routing mechanism considers predicted congestion degree, energy remaining and lowest number of hops to satisfy a path-satisfaction model. This algorithm updates discretely at the time of process of local optimization and considers the learning factor which is changing for updating strategy. This approach relies on active congestion avoidance while taking into account the projected level of node congestion, the smallest amount of hops, and the energy left over for frog generation.

Ad hoc On-demand Multipath Routing with Lifetime Maximization (AOMR-LM) [27] presented is an energy-efficient multipath routing protocol that aims to preserve residual and provide a balanced energy consumption in the network. The path classification mechanism considers the energy level for forming paths. This multipath routing protocol improves network lifetime, reduces end to end delay, and consumes less energy. An Intelligent Water Drops (IWD) inspired routing protocol [28] is a novel routing mechanism designed for Mobile Multihop Adhoc Networks. This technique uses IWD heuristics for developing the packet forwarding concept. In this methodology, the route failure prediction technique is also adopted for determining the route failure time by estimating the link failure time. However, this scheme lacks to support quality of service (QoS) parameters such as support of the real-time application.

A novel mixed approach [29] is presented to enhance the capability of AODV routing protocol. It considers the node capacity of the in between nodes to relay the data packets to the destination. This mechanism considers not only the workload of the node, but also the residual energy of the node. However, this scheme does not focus on performance criterias or metrics such as E2E delay, traffic overhead, link stability, and route acquisition latency. A Preemptive approach [30] of AOMDV protocol is presented to overcome the issues for improving the lifetime of nodes, reduce overhead, and conserved energy consumption of the AOMDV protocol. In this multipath routing mechanism, the historical traffic is considered for improving the network performance and reducing the number of packets switched between nodes. However, this mechanism lacks in responding quickly to link failure and congestion. A weighted QoS multipath routing protocol [31] is designed in Mobile Multihop Adhoc Network based on the path quality, path stability, and QoS awareness. A cross-layer mechanism is adapted for providing path quality, and the route selection is based on a multicriteria selection algorithm. However, this scheme fails to support the reliability of the network

III. DISCUSSION

As we have seen there are diverse requirements of Mobile multihop Ad-hoc Network such as resilience, scalability, reliability, energy imitations etc., hence the selecting appropriate routing protocols is an important and challenging task. Functionality of routing protocol mainly consists of finding optimal paths and later on maintaining the found path. Finding an optimal path consists of different types of measurement parameters. Measurement parameters decide the optimality constraint of the routing protocol. Therefore the present group focused on these performance parameters and summarized them in table 1.

Due to the frequent network topology change, lack of proper optimal routes leads to link failures and high energy consumption. In a Mobile Multihop Ad Hoc Network, the mobile nodes maintain route information, but often the network topology is unpredictable. Therefore, the number of paths and distance of a node from the center are the two parameters affecting the load in routing. Number of protocols presented in literature, and most of the protocols focused on parameters like hop count, end-to-end delay, packet delivery ratio etc. Protocols developed early in the literature mostly concentrated on to reduce the data traffic or to decrease the number of hops present in the route. These protocols were developed without explicitly considering QoS parameters. The main goal of QoS routing is to find the relevant routing, which should meet the QoS constraints, such as packet loss, power consumption, delay, bandwidth, jitter, etc. are all topological transmission characteristics. Therefore the focus on obtaining an optimal number of routing paths is necessary to QoS in a wireless network. By achieving QoS in wireless communication, the delay and stale routes in the network are reduced. In multipath routing, multiple paths are established between a single source and a single destination in order to achieve the smooth delivery of data packets.

Multipath routing is an additional heuristic dimension introduced for overcoming the issues faced in single-path routing specifically for reducing end-to-end delay and packet overhead and maximizing network lifetime [32]. In a Mobile Multihop Ad Hoc Network, link quality plays a vital role in obtaining better QoS in multipath routing protocols. However, due to constant change in network topology, the Mobile Multihop Ad Hoc Network is faced with problems such as frequent link failure, degraded transmission quality, and reduced network throughput. In table number 2, the present group pointed out limitations and features of various multipath routing protocols. For improving the link quality, meta-heuristic mechanisms such as particle swarm optimization, genetic algorithm, and other swarm intelligence mechanisms are applied. In table 1 authors also have included the papers based on meta-heuristic optimization models. However, the drawbacks faced in the existing meta-heuristics optimization models as well as multipath routing protocols are that the improper determination of link availability and link quality resulted in poor network performance. Therefore, to meet the limitations of the multiple goals above, potential new methods or technologies are needed to solve QoS routing. Thus, considering the complexity of the problem, the use of metaheuristics instead of other methods provides an accessible solution. To solve QoS routing, researchers in the past used various metaheuristic algorithms . However, it is necessary to improve the routing protocol in MANETS to provide a stringent QoS improvement

IV. CONCLUSION

In this article, the present group reviewed the current status of multipath routing protocols used in multihop mobile ad-hoc network. Performance of routing protocol is determined by measurement parameters. Present group discussed and listed various measurement parameters used in Mobile multihop ad hoc network. Mobile multihop ad hoc network is dynamic in nature and meta-heuristics approach is well suited in this type of network. Present group also focused on some of the multipath routing protocols from the literature which has used the concept of meta-heuristic approach. Paper discussed the methodology, features and limitations of existing multipath routing protocols. Paper also discussed some findings , future scope by considering the existing research related to this field.

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Table 1: Literature review of Existing Multipath Routing Mechanisms

Papers	**Methodology**	**Features**	**Limitations**
Multipath Battery and Mobility-Aware Routing Scheme (MBMA-OLSR) [17]	To select stable and efficient links, a multicriteria node rank metric comprising residual battery energy and speed of the nodes is applied in MANET routing.	• Multi-criteria based routing decision. • Copes up with link failures during node movement • Balances loads among multipath	• Lacks in supporting scalability • Lacks in achieving tradeoff between energy efficiency and QoS
Ant Colony based Multipath routing mechanism [18]	To satisfy QoS provisioning, an Ant colony model based adaptive routing mechanism is employed, and a dynamic online approach is used for maintaining dynamic control parameters.	• Adaptive distribution of load to multiple path. • Maximizes network performance • Quick response to current network conditions	• Link availability and link stability are not assured.
Energy-efficient multipath routing scheme [19]	Fitness function by considering efficient energy criteria is used as a optimization function to find the optimal path towards the destination node.	• Better packet delivery and throughput • End to end delay is reduced	• Energy consumption, bandwidth and network lifetime are not considered during selection of routing paths
Mobility, Residual energy, and Link quality Aware Multipath (MRLAM) [20]	To determine the optimal route with energy efficiency, the Q-learning algorithm is adopted for selecting intermediate nodes.	• Overall improvement in network performance in terms of energy cost, end to end delay and packet loss ratio.	• High Packet overhead and traffic congestion exist.
Multipath routing protocol with load balancing and energy constraining based AOMDV [21]	To achieve optimal routing, the selection of nodes is based on a lower queue length of the MAC layer interface queue and higher residual energy.	• High residual energy routes are selected for data transfer • Reduces the number of energy exhausted nodes, the average end-to-end delay, and routing discovery frequency.	• Balancing load optimally is not achieved

Load balancing ad hoc on-demand multipath distance vector (LBAOMDV) routing protocol [22]	For improving the reliability of the network, the LBAOMDV protocol considers the path-weight of all available multipath.	• The LBAOMDV protocol ensures reduced node breakdowns, • Enhances the reliability of the MANET.	• Lacks in providing computational efficiency during load balancing
A real-time routing algorithm for MANET [23]	Applies reinforcement learning and Q- Learning algorithm for predicting the behavioral pattern of nodes	• Relies on local data of the neighboring nodes. • Better packet delivery rate	• The optimal routing policy is not allocated.
A Multipath routing strategy [24]	DM-OLSR aims to handle a partial view of the network topology, flooding disruption attacks and load balancing in multipath OLSR-based networks	• Achieves a flexible mechanism to compute multiple disjoint paths between any two nodes of a MANET.	• The overhead due to the excessive number of topology control messages reduces the performance of the network
Bio-inspired routing protocol based on the cuckoo algorithm [25]	A cuckoo algorithm inspired routing algorithm is employed for determining the best path between two nodes	• Better packet delivery ratio and the end to end delay	• Link stability and link availability is not assured
Adaptive multipath routing based on improving the leapfrog algorithm [26]	To solve the transmission congestion problem a shuffled frog-leaping algorithm is employed based on congestion avoidance.	• Reliability is achieved • Prolongs network lifetime	• The algorithm does not achieve efficient load balancing
Ad hoc On-demand Multipath Routing with Lifetime Maximization [27]	To preserve residual energy of nodes, AOMDV-LM protocol uses an energy-aware mechanism for selecting and classifying paths	• Conserves the residual energy of nodes • Balances the consumed energy over multiple paths.	• Accurate determination of the optimal path is not assured due to a single criterion routing decision.
An intelligent water drop inspired routing protocol [28]	To construct and maintain routes between communicating Nodes, intelligent water drops inspired optimization algorithm is applied.	• Anticipates route failures during route failure prediction.	• Lack of satisfying QoS parameters
A Mixed Approach based Multi-path Routing [29]	To enhance the AODV routing protocol, the mixed approach considers the node capacity for relaying the data packets to the destination.	• Load balancing achieved • Efficient utilization of bandwidth	• Lacks in focusing on performance metrics such as end-to-end delay, link stability, traffic overhead, and route acquisition latency.

A Preemptive approach of the AOMDV protocol [30]	To increase the nodes lifetime and reduce overhead in MANET, a preemptive approach is adopted that uses a historical variation of nodes energy values to compute energy variation rate	• Maximize network lifetime • Reduction in overhead • Conserve energy consumption in AOMDV protocol	• This mechanism lacks in responding quickly to link failure and congestion
Weighted QoS aware routing protocol [31]	A Path Quality and Path stability aware routing Protocol is designed for finding a path that satisfies the application requirements in Mobile Ad hoc Networks.	• limit the routing discovery control messages during the route discovery phase	• Lacks in satisfying the reliability factor