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A Survey of various routing protocols in MANETs

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***Abstract*— In the recent past there has been increasing research in Mobile Ad Hoc Networks (MANETs) as they became ubiquitous. The nodes in MANET are resource constrained and designing efficient routing strategies for such network remains a challenging endeavour. Routing strategy when designed intelligently, the network lifetime can be increased besides optimizing utilization of limited resources available. A plethora of routing protocols is already available for MANET. They have been classified into different categories like reactive, proactive and hybrid routing protocols. The routing information update is the basis for this classification. Proactive protocols maintain routing information while reactive protocols do not. However, the hybrid routing protocols leverage the good features of both justifying their category name. One difficulty with routing protocols in MANET is to know which protocol performs best in which situation. Since protocols exhibit advantages and disadvantages based on certain context, it is quite difficult to determine. This paper attempts to provide insights into the facts of proactive, reactive and hybrid routing protocols that are used in MANET. Besides, this paper also throws light into other routing protocols that were proposed from time to time. We intend to extend this research to have experiments in MANET using different protocols in terms of route discovery and route maintenance.**

***Keywords*— Mobile communications, mobile ad hoc networks, routing protocols, comparison.**

I. INTRODUCTION

The inadequate resources in MANETs have made to design an efficient and scalable, reliable routing protocol. An efficient design must use the available limited resources while maintain the adaptability to changes made in network partitioning and topology, apart from these it should also maintain different levels of QOS to different type of the application which are desired by end user. Before increase interest on wireless networks, in wired network two different algorithms were used as they are referred as the 'Link-State Algorithm' and 'Distance Vector Algorithm'. With respect to link-state routing nodes actively participate in updating routing information and broadcast the same to other nodes through flooding. When other nodes receive update packets, it updates its strategy according to network and maintains the shortest path to choose the next-hop for node to reach its destination.

Both algorithms namely distance-vector and traditional link-state cannot scale well for large MANETs. The reason behind this is the periodic route updates and consumes high bandwidth. To overcome this issues many algorithms came into existence for MANETs. These protocols, based on their routing phenomenon, are classified into three types namely proactive, reactive and hybrid routing protocols. As the name implies, the proactive routing protocol maintains and updates routing tables periodically. In case of reactive protocols the routes are determined only when they is a demand using a method known as route discovery. The hybrid routing approaches have the good features of both proactive and reactive protocols.

II. ROUTING PROTOCOLS IN MANETS

The most admired method to categorize the mobile ad-hoc network routing protocol is based on how the nodes maintain and acquire the information. Using this method, MANET routing protocols can be classified into proactive, reactive and hybrid routing. Proactive routing protocols maintain routing tables and hence they are known as table-driven. These protocols facilitate the nodes in MANET to analyse and evaluate routes all destinations nodes and periodic update routing information. This enables source node to get an immediate route path when required, and proactive routing protocol act according to network topology. When there is change in the topology it gathers latest route path information by periodic updates. Using this proactive routing algorithm, nodes needs updating all proactive information like route path, networks traffic strategy despite of traffic presence. Here are some the proactive routing protocols such as WRP, DSDV, and the FSR protocol.

Reactive routing protocols for MANETs are also known as 'on-demand' routing protocol. In the reactive routing protocol, routing paths are found when it's necessary, unlike the proactive routing protocols it doesn't do any periodic update which increases overhead. It continuously determines the route until there is a needed, discovery terminates only when either route has been found or no route is available after successfully discovery process for all permitted routes. In some cases active route may be disconnects due to node mobility. So route maintenance is an important process for reactive routing protocols. While compared to proactive, reactive does less distinctive over head, this an added advantage of reactive routing protocol. Here are some of the reactive routing protocol like AODV, DSR and etc. Hybrid routing protocols are proposed to combine the merits and advantages of the both proactive and reactive routing protocols. Hybrid routing protocols for MANETs utilizes hierarchical architectures. Here are the some of the example of the hybrid protocols like ZRP, ZHLS, and HARP.

Table 1: Classification of Routing Protocols

Name of Protocol	Example of Routing Algorithm
Pro-Active Routing	• Direction Forward Routing Protocol (DFR) • Cluster head Gateway Switch Routing Protocol (CGSR) • Distributed Bellman-Ford Routing Protocol (DBF) • Highly Dynamic Destination-Sequenced Distance Vector routing protocol (DSDV) • Hierarchical State Routing protocol (HSR) • Wireless Routing Protocol (WRP)
Reactive Routing	• Ad-Hoc On demand Distance Vector Routing Protocol (AODV) • Ad-Hoc On demand Multipath Distance Vector Routing Protocol (AOMDV) • Backup Source Routing Protocol (BSR) • Dynamic Source Routing Protocol (DSR)
Flow Oriented Routing	• Signal Stability Routing Protocol (SSR) • Preferred link based routing (PLBR)
Adaptive Routing	• Temporally-Ordered Routing Algorithm routing protocol (TORA)
Hybrid Routing	• Hybrid Routing Protocol for Large Scale Mobile Ad Hoc Networks with Mobile Backbones (HPRLS) • Temporally-Ordered Routing Algorithm routing protocol (TORA) and many others etc.
Hierarchical Routing	• Core Extraction Distributed Ad hoc Routing Protocol (CEDAR) • Distributed Dynamic Routing Algorithm Protocol (DDR) • Global State Routing protocol (GSR) • Hybrid Ad Hoc Routing Protocol (HARP) • Augmented Tree-based Routing protocol (ATR)
Geographical Routing	• Adaptive Location Aided Routing Protocol – Mines protocol (ALARM) • Blind Geographic Routing (BGR) • Distance Routing Effect Algorithm for Mobility protocol (DREAM) • Location-Aided Routing protocol (LAR) • Zone-Based Hierarchical Link State Routing protocol (ZHLR)

The routing protocols can be classified into table driven, demand driven and hybrid. Figure 1 shows the protocols of these categories.

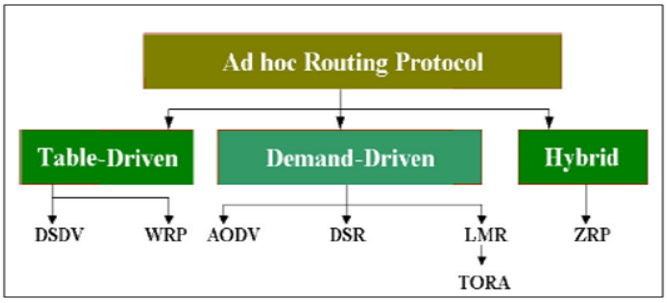

Fig 1 – Routing protocols

As can be seen in Fig 1, the routing protocols are presented based on the features such as table-driven or demand-driven. In the last two decades computing resource became cheaper that paved way for increased usage of different kinds of networks including mobile networks [25]. Since the emergence of mobile networks routing protocol has been a hot topic [14]. Innovations in routing and hybrid routing algorithms can extend life time of wireless networks [16]. A good survey of routing protocols is found in [7] and [8] for WSN and MANET respectively. Wireless infrastructure is fault tolerant, self-optimizing and self-configuring [11]. A good survey of multipath routing protocols like DSR and AODV can be found in [12] to achieve low packet loss ratio and low packet latency. Underwater monitoring with sensor devices also has its applications [26], [28]. An overview of routing protocols for VANET is found in [38]. More insights on three different types of routing algorithms can be found in the subsequent sections of the paper.

Our contributions in this paper include the review of present state-of-the-art on routing protocols that provide valuable insights. The remainder of the paper is structured as follows. Level A focuses on proactive routing protocols. Level B throws light into reactive routing protocols. Level C provides information about hybrid routing protocols. Level D summarizes the essence of all protocols. Level E provides information about other routing protocols. Section III concludes the paper besides providing directions for future work.

A. *PROACTIVE ROUTING PROTOCOLS*

Proactive protocols are the protocols that update routing information frequently to ensure the information is up-to-date. The protocols in this category include DSDV, OLSR and WRP. They are discussed in the ensuring sub sections.

1) Destination-Sequenced Distance-Vector (DSDV)

This is the routing protocol which is based on an algorithm named Bellman-Ford Routing with some enhancements. When compared with other protocols, the distance vector routing is considered less robust due to bouncing effect. As per this protocol each node maintains a routing table that contains all devices in the network. It updates the table periodically. In order to ensure correct information in the routing table, it broadcasts request to all nodes so as to update the routing table. All the neighbor nodes estimate the cost of the routing at present and make a decision by comparing existing value in the route table. If there is updating required the node recomputed cost and the routing table gets updated [40].

2) Optimized Link State Routing Protocol (OLSR)

It is a point to point protocol that employs a link state packet for robust forwarding mechanism known as multipoint relaying. The protocol is aware of two optimizations. They are by reducing the size of control packets and by reducing the number of links. Each node contains topology information. The network follows an approach known as computation of optimal route, efficient flooding and neighbor sensing. When detection of changes is made with respect to neighbors, it is known as neighbor

sensing. An optimal route is computed by each node and the shortest path algorithm is applied for finding optimal path. When a transmission is needed, paths to all nodes will be available and transmission begins immediately with best possible path [40].

3) Wireless Routing Protocol (WRP)

It is a protocol which makes use of table for routing information similar to that of DSDV. It maintains routing information with each node in the network. The routing information contains the shorted path to every destination. It is a loop free routing protocol and proactive in nature. This protocol is nothing but a path finding algorithm without count-to-infinity problem. Each node in the network is supposed to maintain four tables. They are Message Retransmission List (MRL), Link-Cost Table (LCT), Routing Table (RT) and Distance Table (DT). In case of link failure between nodes, the neighbors are informed. Its quantitative performance analysis is found in [5].

4) Fisheye State Routing (FSR)

It maintains accuracy distanced path and its quality information pertaining to its immediate neighbor. As the node distance increase, the amount of detail stored will be reduced. Each node is aware of many neighboring fish-eye scope with 1 and 2 hop reachability. It can effectively reduce the size of update messages. This is achieved by updating network information to neighbors from time to time. It is more scalable with large networks [40].

B. *REACTIVE ROUTING PROTOCOLS*

As the name implies, the reactive routing protocols are given that name as they update routing information based on the demand. There are three reactive routing protocols such as AODV, DSR, and TORA.

1) Ad-Hoc On-Demand Distance Vector (AODV)

As the name implies, Ad Hoc On Demand Distance Vector is a routing protocol which is widely used in MANETs. It is also used in other mobile networks. It was the result of combined effort of many universities such as University of Cincinnati, Santa Barbara and University of California. In this protocol a node sends packets to a particular destination only on-demand. And it maintain routes to destination till they need by the source, it's capable of both unicast and multicast routing.

In AODV, each and every node maintains a table, which contains information about their neighbors to send packets to reach their destination safely. The main key feature of AODV is it ensures the freshness of routes. An ad-hoc network is a collection of mobiles nodes without any interference of access point or existing infrastructure .The AODV uses routing algorithm which is useful for networks where nodes are automatically configured. This protocol is capable of providing loop-free route even in the case of broken links without the need for route advertisements that are made periodically. It also uses symmetric links between neighbor nodes. Nodes do not lie on the active paths. They also do not maintain routing information and do not involve in routing table exchange performed frequently. Moreover, in AODV routing discovery is to destination node is not done unless demanded at the last possible moment. Nodes can also identify their neighbors when local connectivity is required. This is achieved by broadcasting hello packets.

The routing table in the neighborhood nodes gives optimized response time to local movement and provides quick response time for request for establishment of the new routes. The algorithm's primary roles are to broadcast discovery packets, for finding the difference between general topology maintenance, neighborhood detection and local connectivity management. AODV makes use of route entries that are generated on demand. However, they maintain routing information that is of latest. It has also mechanisms to avoid stale data in case of caching. The combination of the features make the algorithm robust in using bandwidth thereby controlling network load, improve responsiveness and ensure loop-free routing.

2) Dynamic Source Routing (DSR)

DSR is one of the on-demand protocols that are best used to reduce bandwidth consumption by the control packets. This protocol eliminates the need for updating routing protocol from time to time. Therefore there is not concept of periodic updates. Route discovery and route maintenance are the two important parts of the protocol. Cache memory is used to *discover* recently used paths. When a node wants to sent a packet, it searches for it in cache. If found, that path is used to transmit data. If not found a route request is sent by the sender to know path for the destination. This process continues until a route is discovered. Once the route is discovered, the packet will be sent to the destination. The packet will reach the destination through intermediary nodes. Every node on the way checks whether the node is sent to itself or not. If the present node is the destination, the packet is received else it is forwarded [40].

3) Temporally– Ordered Routing Algorithm (TORA)

This protocol is loop free, highly adaptive and distributed routing algorithm. This algorithm is based on the link reversal concept. It makes use of Direct Acyclic Graph (DAG) for defining upstream and downstream routes. With more number of nodes in network, the TORA protocol provides better route aid. It is relatively complicated protocol but supports control messages in case of link failures. In contrast to other protocols TORA will be able to recover point of failure directly. It exhibits high overhead for small networks.

C. *HYBRID ROUTING PROTOCOLS*

These are the protocols that employ different aspects of proactive and reactive protocols. The hybrid protocols that leverage good features of both proactive and reactive protocols are ZRP, ZHLS, DST, and DDR. The following sub sections provide more details of them.

1) Zone Routing Protocol (ZRP)

It is the routing protocol which considers nodes into different sub networks or zones. It combines the good features of both on-demand and proactive routing protocols for best performance. At zone level proactive routing is employed for high speed communication. However, the inter-zone communication needs to use on-demand approach. Based on the distances, the network is divided

into number of routing zones. Zone routing determines the size of zone while independent zone routing relaxes this constraint. The latter approach is adaptive and improves scalability. Inside a zone every node updates routing information periodically besides local route optimization from time to time. The optimization includes detection of link failures, shortening of routes, and getting rid of redundant routes [40].

2) Core Extraction Distributed Ad Hoc Routing (CEDAR)

It is a protocol with partitioning and it has integrated QoS support. Each partition has a Dominator Node (DN). A graph is built with a Dominator Set (DS) that contains all dominators of all partitions. A reactive routing protocol is employed for core nodes. The three important phases in the protocol include establishment of routing infrastructure, link-states of high bandwidth and their propagation, and QoS route computation. Fast moving increasing waves and slow moving increasing waves are used to propagate link information. They represent both increase and decrease of bandwidth [40].

3) Zone Based Hierarchical Link State Routing Protocol (ZHLS)

This protocol is based on hierarchical structure. According to this protocol, the network is divided into multiple parts or zones without overlapping. Each node is identified by both zone ID and node ID. Therefore the network contains two level structures for its topology. It also exhibits two types of link state updates. They are known as node level and zone level link state updates. A node level LSP is broadcasted to the other nodes of the zone periodically. Thus the nodes in a single zone will have similar state information. Before transmission starts a node checks intra-zone first and knows whether the destination lies in the same one or different zone. If found in the local zone routing table, it can send data to destination. Otherwise, it has to request all other zones to know the destination's location. Once it is known, the source will be able to send data to destination. This protocol has low routing overhead when compared with DSR and AODV [40].

4) Distributed Dynamic Routing Algorithm Protocol (DDR)

It is a tree based routing protocol that does not need root node. Periodic beaconing messages are used to construct trees. And these messages are periodically exchanged among neighboring nodes. Within a given network, these trees form a forest with gateway nodes that act as links between them. The gateway nodes are also regular nodes but they belong to separate trees and they are within the range of transmission of other nodes. Thus the whole network appears to have many overlapping zones. There are six phases in the algorithm. Neighbor election, intra-tree clustering, inter-tree clustering, forest construction, zone naming and zone partitioning are the six phases in the protocol. It does not depend on the static zone map unlike ZHLS. Moreover it does not need a root node to facilitate data transfer between different nodes [40].

D. *SUMMARY OF ROUTING PROTOCOLS*

We summarize different categories of routing protocols here. This section throws light into the insights of proactive, reactive and hybrid protocols in terms of route updates, loop free nature, routing overhead, caching overhead, throughput, routing tables and so on. With respect to proactive routing protocols the parameters are as follows. DSDV exhibits periodic route updates, loop free, high rooting overhead, medium caching overhead, low throughput and 2 routing tables are required. WRP exhibits periodic route updates, loop free, high rooting overhead, high caching overhead, low throughput and 4 routing tables are required. OLSR exhibits periodic route updates, loop free, low rooting overhead, high caching overhead, medium throughput and 4 routing tables are required.

With respect to reactive routing protocols AODV exhibits features like route creation by source, no periodic updation, speed is used as performance metric, high routing overhead, low caching overhead, high throughput, no multipath routing, and route updation is non-periodic. DSR exhibits features like route creation by source, no periodic updation, shortness is used as performance metric, high routing overhead, high caching overhead, low throughput, supports multipath routing, and the route updating is non-periodic. TORA exhibits features like route creation locally, no periodic updating, speed is used as performance metric, high routing overhead, medium caching overhead, low throughput, supports multipath routing, route updation is with high routing overhead.

With respect to hybrid routing protocols, ZRP exhibits flat routing structure, no support for multiple routes, supports beacons, route information stored in either intrazone or interzone tables, route metric is shortest path, advantage is reduced transmissions, and the drawback is issues with overlapping zones. ZHLS exhibits hierarchical routing structure, support for multiple routes, no support for beacons, route information stored in either intrazone or interzone tables, route metric is shortest path, advantage is low control overhead, and the drawback is that it needs static zone mapping. DST exhibits hierarchical routing structure, support for multiple routes, no support for beacons, route information stored in route tables, route metric is the ability to forward using the tree neighbors, advantage is the reduced transmission, and the drawback is issues with root node. DDR exhibits hierarchical routing structure, support for multiple routes, support for beacons, route information stored in either intrazone or interzone tables, route metric is stable routing, advantage is does not need zone mapping, and the drawback is issues with neighbors as they become bottlenecks.

We end the summary with the comparison of the protocols at category level. The parameters considered for the comparison at this level include routing philosophy, routing information, scalability, delay, periodic route updates, route availability, and storage requirements. Proactive or table-driven protocols exhibit higher storage requirements, routes are always available, periodic route updates are always required, low delay, scalability for 100 nodes, high control traffic, routing information is stored in table, and routing philosophy is mostly flat. Reactive or on-

demand protocols exhibit storage requirements based on number of routes maintained, routes are computed as per need, periodic route updates are not required, high delay, scalability for more than 100 nodes, low control traffic, routing information is not stored, and routing philosophy is flat. Hybrid protocols exhibit storage requirements based on size of clusters, routes are available based on location of destination, periodic route updates are used inside each zone, delay is low for local destination and high for interzone, scalability for greater than 1000 nodes, control traffic is lower than other two categories, routing information storage depends on requirement, and routing philosophy is hierarchical. Performance comparison of the three categories can be found in [1], [2]. Etiquette policies are compared between reactive and proactive protocols in [3].

E. *Other Routing Protocols*

Aggelou & Tafazolli [4] proposed a new routing protocol named Relative Distance Micro-Discovery Ad Hoc Routing (RDMAR) which is bandwidth-efficient with minimum routing overhead and congestion. Pei *et al.* [6] proposed a routing protocol named Hierarchical State Routing (HSR) with group mobility. Bajaber & Awan [9] proposed a novel protocol named Adaptive Decentralized Re-Clustering Protocol (ADRP) for WSN for longer life time of network. Wang *et al*. [10] proposed a hybrid routing algorithm named HOPNET. It is based on Ant Colony Optimization and one zone routing and known for high scalability. Rajagopalan & Shen [13] proposed a new hybrid protocol for MANET. It is known as Ad Hoc Networking with Swam Intelligence (ANSI) which is congestion aware. For dense and highly dynamic MANETs Whitbeck & Canan [15] proposed a hybrid protocol known as Hybrid DTN-MANET which proved to exhibit high performance. Vecchio *et al*. [17] proposed a protocol named DEEP for WSN for proactive data dissemination. The similarities and differences between routing protocols of P2P networks and MANETs are explored in [18]. Zhang *et al*. [19] proposed a hybrid routing protocol for Wireless Mesh Networks (WMNs). A routing algorithm named FRANCA was proposed in [20] for interoperability between wireless networks and Bluetooth networks. Souihli *et al*. [21] explored load balancing MANET for high network performance. Game theory is often used in computer networks to ensure secure communications. Routing protocol was proposed based on game theoretic approach in [22]. Lee & Kim [23] proposed a multi-cast routing protocol named Neighbor-Supporting Multicast Protocol (NSMP) for MANET to reduce route maintenance overhead and control overhead by utilizing node locality. Scalability comparison between AODV and AOMDV revealed that scaled better than AODV [24].

Source Routing with Local Recovery (SRLR) is another routing protocol implemented by Sengul & Kravets [27] for efficient local recovery besides reducing overhead. Kim & Lee [29] proposed a routing protocol for Vehicular Ad Hoc Network (VANET) for identifying reliable paths. Swam intelligence was discussed in [30], [31] for adaptive routing. Handover performance was studied in [32] between reactive and proactive routing protocols and found comparable performances.

Manvi & Kakkasageri [33] proposed a protocol named Agent Based Multicast Routing (ABMR) for multicast routing in MANET for rendering adaptable and flexible services. Que & Ganz [34] proposed a routing algorithm known as Ad Hoc QoS On-Demand Routing (AQOR) for improving quality of services. With OLSR two metrics were compared. The metrics are ETX metric and hysteresis routing metric. The latter showed high performance [35]. There were network coding aware routing protocols as explored in [36] for high throughput and low delay. Rango *et al*. [37] proposed a protocol named Constrained Cost-Bandwidth-Delay Genetic Algorithm (CCBD-GA) for quality of services. Ahn [39] presents Gathering Based Routing Protocol (GRP) for fast transfer of packets. Hybrid Bee swam Routing (HyBR) was proposed by Bitam *et al*. [40] for safety in VANET.

III. CONCLUSIONS

In this paper we study routing protocols in MANET. Since MANETs are convenient networks in emergency situations, the nodes in the network are resource constrained. In this context, the life time of network is less and that time is valuable for having emergency communications. Efficiency of routing protocols plays a role in having robust communications and also reduces resource consumption significantly. This leads to the increase of network lifetime. Though there are many existing protocols for routing in MANET, there is ever need for optimizing them. Therefore there is much research interest in this area. As the existing protocols for routing have been classified into different categories like reactive, proactive and hybrid routing protocols, it is essential to have insights about them with good technical knowhow for expert decision making. However, it is quite difficult to determine which routing protocol is best in given scenario. Towards this end, in this paper, we review the present state-of-the-art of MANET routing protocols, their merits and demerits in the context of different categories of MANET protocols based on their routing information maintenance. This paper throws light into the merits and demerits of the proactive, reactive and hybrid protocols. This research will be extended further to evaluate route discovery and route maintenance with respect to MANET protocols.

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