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A COMPREHENSIVE REVIEW OF ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORKS (MANETS)

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Abstract
Network routing has been one of the most investigated areas in computing networking for decades. Many studies on wired and wireless networks have been conducted. More research fields for network routing technology have emerged as a result of recent technological advancements. In recent years, research into ad hoc networks such as wireless sensor networks (WSN), vehicular ad hoc network (VANET), wireless mesh network (WMN), and mobile ad hoc network (MANET) has increased. Due to the mobile nature of a lot of gadgets we use this days, the researchers embarked on a review to comprehensively show the various routing protocol technology that one can adopts when implementing a network routing scheme for MANETs. Types of routing protocols, classifications, routing techniques, geographical coverage, route metric, route repository and route reconfiguration strategies are covered in detail. The various routing protocols covered in this study were compared in this paper. The protocols' areas of strength were highlighted and network simulators that had these protocols enabled by default were also x-rayed.

1.0 INTRODUCTION

Ad Hoc is a term that comes from the Latin phrase "for this purpose," and it's frequently used to describe solutions that are devised on the spot. In computer networking, an ad hoc network is a type of computer network that occurs when devices communicate without the help of a wireless base station [1]. The most prevalent type of ad hoc network is wireless local wireless networks (WLANs) (LANs). The devices interact directly with one another, rather than relying on a base station or access points like Wi-Fi LANs to coordinate data delivery. Each device participates in a routing activity by determining the path and transferring data to other devices using a routing algorithm [2]. Mobile Ad hoc Networks (MANETs) are networks in which all normally mobile nodes in nature and the routers (nodes) are not fixed. Each MANET device is free to move about and connect to other devices on a regular basis. Each data packet must be transmitted to its intended destination, necessitating the use of a router. These type of networks are utilized for battleground communication, destructive recovery, and rescue operations when the wired network is inaccessible [2].Tactical networks in military operations, emergency services, patient records retrieval, sensor networks in weather forecasting and monitoring, earth movement capturing, ocean engineering, real-time data collection, cellular networks and Bluetooth, video conferencing, virtual classrooms, and so on are other areas of application for Mobile ad hoc networks [2], [3].

Ad hoc networks work devoid of base station that serves as router. Each intermediary nodes functions as a router, and the source nodes send their messages through these nodes. As a result, sent packets is received by the destination from its sender, each node forwards packets to next nodes until packet arrives the destination node. From source to destination, data is transported over multiple hops. Multi-hop transmissions among nodes on the same channel are vital in ad hoc networks. The intermediary nodes serve as a conduit for communication between nodes. In an ad hoc network setting, each node's performance and availability are critical.

2.0 CLASSIFICATIONS OF MANET ROUTING PROTOCOLS

Due to node mobility issue (Nodes constantly changing position) in MANETs, efficient routing protocols is needed for effective communication in MANETs. From various publications and articles around the internet, we have basically three (3) classes of MANET routing protocols namely proactive, reactive and hybrid protocols. In this study, the researchers examined the attributes for various MANET routing protocols. They are classified as follows:

- Proactive
- Reactive
- Hybrid and
- Others

Other classifications of routing protocols that do not fit the categories above are

- Geographical
- Power-aware
- Multipath
- Hierarchical
- Multicast
- Geographical multicast

2.1. Proactive Routing Protocols

They are table-driven routing schemes that try to keep track of current network pathways in a database known as routing table. The routing information is stored in a table on each node in the network. The nodes share topological information so that they may all see the network from the same perspective. The information transmitted aids in the reflection of any changes in the topology. When a node needs to send a message, it simply looks up the path to the destination in the routing table. The message is not delayed as a result of the remote route finding. The overhead of maintaining an up to date routing tables is its greatest challenge [4], [5]. Examples of protocols under this category includes:

- **B.A.T.M.A.N:** This proactive routing protocol was created by a consortium of German community members to substitute the optimized link state routing protocol (OLSR). BATMAN which stands for Better Approach to Mobile Ad-hoc Networking. This routing protocol is for multi-hop mobile ad hoc networks (MANETs). A key feature of B.A.T.M.A.N is that no single node has all of the information about the network, it decentralizes the knowledge about the optimal path across the network. This approach removes the requirement for network modifications to be broadcast to every node in the network. The individual node simply keeps track of the "direction" from which it receives data and sends it in that direction. Data is transferred from one node to the next, and packets are given unique, dynamically generated routes [6].
- **Babel:** Babel is a fast-converging distance-vector routing protocol that avoids loops in IPv6 and IPv4. It is based on the concepts of DSDV, AODV, and Cisco's EIGRP, but it is intended to work in both wired and wireless networks, such as Wireless Mesh Networks and Mobile Ad hoc Networks [7].

  It knows and maintains routes to all network destinations before they are used because it is a proactive protocol. It knows and maintains routes to all network destinations before they are used because it is a proactive protocol. The absence of route discovery delay in the routing table has made this routing protocol beneficial for some systems and network applications [8].

- **Destination Sequence Distance Vector (DSDV):** it is a vector routing system that needs each node to communicate routing changes on a frequent basis. Based on changes to the Bellman-Ford routing mechanism, DSDV uses the table-driven routing mechanism. A routing table is stored on each network node and specifies all of the network's destinations as well as the number of hops required to reach them. Each item has a sequence number that can be used to identify stale entries. This approach avoids routing loops in the protocol from arising [9].
- ***Optimized link state routing (OLSR)*:** The OLSR, a proactive routing protocol based on link state routing, was proposed by [8]. For mobile ad hoc networks, OLSR protocol was created. It works as a proactive, table-driven protocol that often exchanges topological information with other network nodes. It is a proactive link-state routing protocol. Throughout the ad hoc network, OLSR sends and receives hello and topology control messages to discover and distribute link state information.

Other proactive Protocols as highlighted by [5] are:

- Wireless routing protocol (WRP).
- Source tree adaptive routing protocol (STAR).
- OLSR with quality of service (QOLSR).
- Hierarchical OLSR for mobile ad hoc networks (HOLSR).
- Cluster head gateway switch routing protocols (C such calculaGSR).

Table 1: Comparism of proactive routing protocols.

Protocol	RS	Routing tables	No. of tables	HM	Update frequency	Critical node	RM	CC	TC
Babel	F	Yes	2	Yes	Periodic	NO	Hop-count	O(n)	O(d)
BATMAN	F	Yes	1	No	Periodic with neighbor	No	Hop-count	O(n)	O(d)
CGSR	H	Yes	2	No	Periodic	Yes, cluster head	Hop-count	O(n)	O(d)
DSDV	F	Yes	2	Yes	Periodic	No	Hop-count	O(n)	O(d)
HOLSR	H	Yes	3	Yes	Periodic	Yes, cluster head	Hop-count	O(n)	O(d)
OLSR	F	Yes	3	Yes	Periodic	No	Hop-count	O(n)	O(d)
QOLSR	H	Yes	3	Yes	Periodic	No	Delay, bandwidth, hop-count	O(n)	O(d)
STAR	H	Yes	1	No	Only at specific events	No	Hop-count	O(n)	O(d)
WRP	F	Yes	4	Yes	Periodic	No	Hop-count	O(n)	O(d)

Table Key:
RS = routing structure; H = hierarchical; F = flat; CC = communication complexity; TC = time complexity; n = number of nodes in the network; d = diameter of the network; RM = routing metric.

2.2. Reactive Routing Protocols

The Reactive Routing protocol is a MANET-based on-demand routing protocol that saves bandwidth. Whenever a sender node needs to transfer data packets to a receiver node, the sender node commences the route search process in this protocol. As a result, the demand for a route initiates the route search process, hence the name "reactive protocol." The network layer (Layer 3 of the OSI reference model) of mobile nodes implements reactive protocols. The mechanisms utilized for routing are the Route Discovery and Route Maintenance functions [5], [10]. Examples of protocols under this category includes:

- **ABR - Associativity-Based Routing:** The associativity-based routing (ABR) is an effective routing system that chooses a route based on nodes' associativity states, which indicate moments of stability. As a result, the routes chosen are more likely to be long-lived, requiring less frequent restarts and resulting in increased throughput. On a need-by-need basis, route requests are broadcast. The integration into a BS-oriented Wireless LAN (WLAN) environment is made possible due to its association feature which enables fault tolerance in the event of BS failure [11], [12].

- **Ad hoc on-demand distance vector (AODV):** It is built to self-start in a network of mobile nodes and to endure a wide range of network behaviors, including node mobility, connection failures, and loss of packets. AODV keeps a routing table at each node. A next hop node, a sequence number, and a hop count are all required fields in a destination's routing table entry. The next hop node receives all packets destined for the destination. The sequence number is a measure of a route's freshness and works as a form of time-stamping. The current distance to the destination node is expressed by the hop count [13].
- **Ant colony based routing algorithm (ARA):** is a swarm intelligence based routing protocol that is multi-hop that in nature and uses the Meta heuristic of ant colony. This methodology uses swarm intelligence to mathematics and engineering challenges, resulting in a highly adaptable, efficient, and scalable routing protocol [14].
- **Dynamic source routing (DSR):** DSR is a lightweight routing protocol for mobile nodes in multi-hop wireless ad hoc networks. Again with no existing network infrastructure or administration, DSR allows the network to be totally self-organized and self-configured. The "Route Discovery" and "Route Maintenance," are protocol is made up of two primary mechanisms used by this protocol to operate together and allow nodes in the ad hoc network to identify and maintain routes to any destination. All components of the protocol are totally on-demand, allowing DSR's routing packet overhead to dynamically scale to only that which is required to respond to changes in the routes currently in use [15].
- **Link-life base routing protocol:** is an adaptable distributed routing system that is stable for ad hoc networks that employs the worst-case duration of communication links, as determined by linear regression of the variance in distance between nodes in the routing metric. To achieve efficient routing, it uses an efficient beaconing method, load balancing, and pro-active and reactive route reconfiguration algorithms [16].
- **Signal stability-based adaptive routing (SSBR**): is an adaptable distributed routing system for ad hoc networks that routes according to signal strength and location stability. As a result of the route strategy, the final path from source to destination is entirely comprised of strong links. When there are several available routes, the destination selects one [17].
- **Temporally ordered routing algorithm (TORA**): is based on the link reversal algorithm which is a highly adaptive, efficient, loop-free, and scalable routing protocol. TORA is intended to reduce communication cost in ad hoc networks by reacting to local network dynamics. The localization of control packets to a limited region (set of nodes) near the occurrence of topological changes due to route break is another key element of the TORA routing protocol. As a result, each network node has to have its own local routing and topology knowledge about neighboring nodes [18].

Other Reactive Protocols as highlighted by [5] are:

- Routing on-demand a cyclic multipath (ROAM).
- Labeled successor routing (LSR).
- Labeled distance routing (LDR).
- Hint based probabilistic protocol (HBPP).
- Gathering based routing protocol (GRP).
- Dynamic backup routes routing protocol (DBR2P).
- Distributed ant routing (DAR).
- Ad hoc QoS on-demand routing (AQOR).

Table 2. Comparism of reactive routing protocols

Protocol	RS	Beacons	Route metrics	Route repository	Route reconfiguration strategy	CC	TC
ABR	F	Yes	Degree of association stability	RT	Local broad cast query	O(n + y)—during route discovery O(x + y)—during route maintenance	O(d + z)—during route discovery O(l + z)—during route maintenance

AODV	F	Yes	Hop-count	RT	SN and new route	O(2n)	O(2d)
AQOR	F	Yes	Bandwidth	RT	Initiate from destination	O(2n)	O(2d)
ARA	F	No	Hop-count	RT	Alternate route or back track until new route is identified	O(n + r)—during route discovery O(n + a)—during route maintenance	O(d + p)
DAR	F	No	Weighted probabilities	Stochastic RT	New route by forward ant	O(2n)	O(2d)
DBR2P	F	No	Hop-count	None	Local repair	O(2n)	O(2d)
DSR	F	No	Hop-count	RC	SN and new route	O(2n)	O(2d)
GRP	F	No	Hop-count	RC	Route backup	O(2n)	O(2d + 1)
LDR	F	No	Hop-count	RT	SN and new route/local repair	O(2n)	O(2d)
LSR	F	No	Relay sequence label	RT	SN and new route/local repair	O(2n)	O(2d)
ROAM	F	No	Hop-count	RT	Erase route and start a new search to get new route	O(|e|)—during route discovery O(6Ga)—during route maintenance	O(d)—during route discovery O(x)—during route maintenance
SSBR	F	Yes	Strong signal strength	RT	SN and new route	O(n + y)—during route discovery O(x + y)—during route maintenance	O(d + z)—during route discovery O(l + z)—during route maintenance
TORA	F	No	Hop-count	RT	Link reversal and route repair	O(2n)—during route discovery O(2a)—during route maintenance	O(2d)

Table Key:
RS = routing structure; H = hierarchical; F = flat routing repository; RC = route cache; RT = route table; RM = route metric; SP = shortest path; CC = communication complexity; TC = time complexity; n = number of nodes in the network, d = diameter of the network, |e| = number of edges on the network, g = maximum degree of the router, l = diameter of the affected network segment, z = diameter of the directed path where the REPLY packet transits, y = total number of nodes forming the directed path where the Reply packet transmits, p = diameter of direct path of the reply, x = number of clusters.

2.3. Hybrid Routing Protocols

Hybrid protocols are created by combining proactive and reactive protocols. Their design combines the benefits of both proactive and reactive techniques to obtain superior results. The hierarchical network paradigm is used to structure the majority of hybrid routing algorithms. To begin, proactive routing is employed to collect any previously unknown routing data. Reactive routing approaches are used to keep the routing information updated when the topology changes [4], [5].

Large networks with several nodes benefit from the hybrid routing protocol. The strengths of both proactive and reactive protocols were utilized in the construction of these protocols. Examples of protocols under this category includes:

- Distributed dynamic routing (DDR): is used in mobile ad hoc networks, as a simple loop-free bandwidth-efficient distributed routing technique. It accomplishes multiple objectives at the same time. To begin with, it offers a variety of strategies for reducing routing complexity and improving delay performance. Second, it is infrastructure-free in the sense that it does not require physical location information. Finally, zone name is done dynamically, and broadcasting is much minimized [19].
- Fisheye state routing (FSR): FSR is based on Pei et al. (2000) link state routing algorithm. The fisheye approach entails keeping an up-to-date collection of distance and path quality information for a node's immediate neighborhood, as opposed to progressively less up-to-date information as the distance grows. Fisheye is a good

compromise between the routing function's accuracy and the overhead caused by the routing protocol's control message creation. FSRs are more suitable for large networks [20].

- Landmark ad hoc routing (LANMAR): is a routing protocol that combines the best of fisheye state routing (FSR) and landmark routing. Landmarks are leveraged for each group of nodes that travel together to reduce the cost of routing updates, . Just like in FSR, nodes only share link status with their neighbors. Routes are precise within the fisheye frame, however routes to distant clusters of nodes are "summarized" by appropriate landmarks. When a packet is transmitted to a faraway location, it first looks for a landmark, then switches to the more exact path provided by fisheye as it comes closer to the target [21].
- Zone routing protocol (ZRP): is a hybrid routing protocol that merges the proactive intrazone routing mechanism of (IARP) with the reactive interzone routing mechanism of IERP. If the destination of a packet is in the same zone as the origin, the proactive protocol is used to transport the packet immediately using a previously saved routing table. A reactive protocol takes over if the route extends beyond the packet's originating zone, examining each succeeding zone in the route to see if the destination is within that zone. This reduces the time it takes to process specific routes. After a zone is validated to include the target node, the stored routing table listing is utilized to broadcast the packet [22].

Other Reactive Protocols as highlighted by [5] are:

- Zone based hierarchical link state routing protocol (ZHLS)
- Relative distance micro-discovery ad hoc routing (RDMAR).
- Mobility aware protocol (MAP).
- Link reliability based hybrid routing (LRHR).
- Hybrid ant colony optimization (HOPNET).
- Fisheye zone routing protocol (FZRP).
- Distributed spanning tree (DST) routing.

Table 3. Comparism of Hybrid routing protocols.

Protocol	RS	Multiple routes	Beacons	RM	Route repository	Route rebuilding	Critical node	CC	TC
DDR	H	Yes	Yes	Stable routing	Intrazone and interzone RT	SN	Yes	Intra-O(Z_N) Inter-O(N + V)	Intra-O(I) Inter-O(2D)
DST	H	Yes	No	Power consumed, hop count	RT	Holding time or shuttling	Yes	Intra-O(Z_N) Inter-O(N)	Intra-O(Z_D) Inter-O(D)
FSR	F	No	No	Scope range	RT	SN	No	O(N)	O(D)
FZRP	H	No	Yes	Hop-count	Intrazone and interzone RT	Route repair at failure point	Yes	O(n)	O(D)
HOPNET	H	No	No	Hop-count	Intrazone and interzone RT	Route repair at failure point	Yes	O(n)	O(D)
LANMAR	H	No	Yes	Hop count	RT at landmark node	SN	Yes	O(N)	O(D)
LRHR	F	Yes	Yes	Edge weight	RC,RT	New route discovery	No	O(n)	O(D)
RDMAR	F	No	No	Hop count	RT	SN and new route	No	O(N)	O(D)
ZHLS	H	Yes	No	End-end delay, packet loss percentage	Intrazone and interzone RT	Location request sent	Yes	During route discovery Intra-O(N/M) Inter-O(N + V) During	Intra-O(I) Inter-O(D)

								route maintenance Intra-$O(N/M)^a$ Inter-$O(N + V)$	
ZRP	F	No	Yes	Throughput, end-end delay, packet loss percentage	Intrazone and interzone RT	Route repair at failure point	Yes	Intra-$O(Z_N)$ Inter-$O(N + V)$	Intra-$O(I)$ Inter-$O(2D)$

Table Key:
RS = routing structure; RC = route cache; H = hierarchical; F = flat routing repository; RT = route table; RM = route metric; d = diameter of the network, SP = shortest path; CC = communication complexity; y = total number of nodes forming the directed path where the Reply packet transmits, n = number of nodes in the network, |e| = number of edges on the network, g = maximum degree of the router, TC = time complexity; z = diameter of the directed path where the REPLY packet transits, p = diameter of direct path of the reply, l = diameter of the affected network segment, x = number of clusters.

3.0 OTHER PROTOCOLS

Research have shown that several other MANET routing protocols exit. They are protocols that are neither solely proactive nor reactive in nature. They are also not considered as hybrid because they contain other features that makes them to be classified differently. Rajeswari (2020) highlighted these MANET protocols and categorized them as the following

3.1. Geographical multicast (Geocast) routing protocols

Geocast routing is the process of sending data to a group of destinations in a network based on their geographical positions [23]. Some routing methods for mobile ad hoc networks employ it as a specialized kind of multicast addressing protocol. Both geographical and multicast routing protocols are incorporated in geocast routing protocols. Geocast routing protocols have a number of advantages, including improved performance and reduced control overhead.
Examples of protocols under this category includes:

- Direction guided routing (DGR).
- Geocast adaptive mesh environment for routing (GAMER).
- Geocast protocol for mobile ad hoc network based on GRID (GEOGRID).
- Geocasting in mobile ad hoc networks (GeoTORA).

Table 4. Comparism of Geocast routing protocols.

Protocol	RS	Core/broadcast	Route metrics	Forwarding strategy	Route repository	Critical node
DGR	H	Core	SP	Limited flooding	RC	Yes
GAMER	F	Core	SP	Source routing	RC	No
GeoGrid	H	Core	Hop count	Flooding or ticket based	None	No
GeoTora	H	Broadcast	SP	Limited flooding	RT	Yes

Table Key:
RS = routing structure; RC = route cache; F = flat; SP = shortest path; H = hierarchical;
RT = route table.

3.2. Power-aware Routing Protocols

When it comes to routing, especially in MANET, power is a valuable resource. Nodes are continually moving and movable. To stay alive and operate as routers during routing, these

nodes require sufficient power. These protocols are made with power conservation in mind. Energy-aware routing protocols are another name for them [24], [25].
Examples of protocols under this category includes:

- CLUSTERPOW and MINPOW.
- Device and energy aware routing (DEAR).
- Energy conserving routing in wireless ad hoc networks.
- Interference aware cooperative routing.
- Minimum energy hierarchical dynamic source routing (MEHDSR).
- Power conserving routing with entropy-constrained algorithm.

Table 5. Power-aware Comparism

Protocol	RT	Type	Path strategy	Routing metrics	Scalability	Robustness	Critical node
CLUSTERPOW	Yes	Clustered	Single-path	Total consumed power	Yes	Yes	Yes
DEAR	Yes	Global	Single-path	Based upon 'device type'	No	Yes	No
Karayiannis and Nadella	No	Distributed	Single-path	Link cost and link reliability	Yes	No	No
Mahmood and Comaniciu	No	Distributed	Single-path	Energy and interference	No	No	No
MEHDSR	No	Global	Single-path	SP or next available link	Yes	No	No
Scott and Bombos	No	Centralized	Single-path	Multiple constrained SP	Yes	No	No

Table Key:
Routing metrics: SP = shortest path.

3.3. Multipath Routing Protocols

The basic goals of multipath routing protocols are to offer reliable communication, load balancing, and to improve the quality of service (QoS) in an ad hoc setting. Challenges like discovering and maintaining multiple pathways are addressed by Multipath routing protocol [26], [27].
Examples of protocols under this category includes:

- Ad hoc on-demand multipath distance vector routing (AOMDV).
- Braided multipath routing (BMR
- Caching and multipath routing protocol (CHAMP).
- Disjoint multipath routing using colored trees:
- Energy and mobility aware geographical multipath routing protocols (EM-GMR).
- Scalable multipath on-demand routing (SMORT).
- Secure multipath routing (secMR).
- Split multipath routing (SMR):
- Truth multipath routing protocol (TMRP).

Table 6. Multipath routing protocol

Protocol	Proactive/reactive	Loops	Route metrics	Route cache
AOMDV	Reactive	No	Advertised hop count	No
CHAMP	Reactive	Yes	Shortest path	Yes
Ramasubramanian et al.	Proactive	No	Preferred neighbor	Route table
SMORT	Reactive	No	Shortest path	Yes
SMR	Reactive	No	Least delay	No
TMRP	Reactive	No	Auction winner	No

3.4. Hierarchical Routing Protocols

Clustering techniques are used to create a hierarchy of nodes in this protocol. Zones are made up of nodes that are grouped together. There are one or more clusters and gateways in each cluster. Hierarchical routing systems were created with the goal of addressing

Scalability concerns in ad hoc networks while minimizing overhead. On the other hand, this adds to the complexity of the routing mechanisms employed by these protocols [28]. Examples of protocols under this category includes:

- Core-extraction distributed ad hoc routing (CEDAR).

- Dynamic address approach
- Hierarchical landmark routing (H-LANMAR).
- Hierarchical state routing (HSR).

Table 7. Hierarchical routing protocols

Protocol	Routing tables	No. of routing tables	Update frequency	Hello message	Critical node
CEDAR	Yes	1	On demand	No	Yes
Eriksson et al.	Yes	2	Periodic	No	No
H-LANMAR	Yes	2	Periodic	No	Yes
HSR	Yes	2	Periodic, within each subset	Yes	Yes, cluster head

3.5. Multicast Routing Protocols

Data is sent from a single source to numerous recipients using multicasting routing. Tree-based multicast and mesh-based multicast protocols are the two types of multicast protocols. The tree-based multicast routing methods make optimal use of network resources. Mesh-based protocols have a high packet delivery ratio and are robust due to the construction of many redundant pathways between nodes [29];

Examples of protocols under this category includes:

- Ad hoc multicast routing protocol (AMRoute).
- Adaptive demand-driver multicast routing (ADMR).
- Ad hoc QoS multicasting (AQM).
- Differential destination multicast (DDM).
- Dynamic core based multicast routing (DCMP).
- Epidemic-based reliable and adaptive multicast for mobile ad hoc networks (Eramobile).
- QoS multicast routing protocols for clustering mobile ad hoc networks (QMRPCAH).

Table 8. Multi cast routing protocol Comparism

Protocol	RS	Core/broadcast	Route metrics	Forwarding strategy	Route repository	Critical node
ADMR	H	Neither	Link breaks	Flooding/tree based	RT	Yes
AMRoute	H	Core	Unicast operation	Shared tree	Based upon algorithm	Yes
AQM	F	Core	QoS	Source routing	RT	No
CBM	F	Core	Threat arrival	Limited broadcast	RC	Yes
DCMP	F	Core	New route	Source routing	RT	No
DDM	F	Neither	SP	Source routing	None	No
EraMobile	F	Neither	Randomly selected	Local broadcast	None	Yes
Li et al.	F	Neither	Minimum energy	Source routing	RC	No
QMRPCAH	H	Broadcast	QoS	Bordercast	RT	Yes

Table Key:
RS = routing structure; F = flat routing repository; RC = route cache; H = hierarchical; RT = route table.

3.5. Location-aware routing protocols

In this group of protocols, another node collects geographical information about a node using the GPS technique. The ad hoc network's scalability can be improved by using location-aware routing protocols [30]. Examples of protocols under this category includes:

- A region based routing protocol for wireless mobile ad hoc networks (REGR).
- Adaptive location aided mobile ad hoc network routing (ALARM).

- Distance routing effect algorithm (DREAM).
- Dynamic route maintenance (DRM) for geographical forwarding.
- Geographical landmark routing (GLR).
- Greedy perimeter stateless routing (GPSR).
- Location aided knowledge extraction routing for mobile ad hoc networks (LAKER).
- Location aided routing (LAR).
- Maximum expectation within transmission range (MER).
- On-demand geographical path routing (OGRP).
- Secure position based routing protocol (SPBR).
- SOLAR.

Table 9. Location-aware routing protocol Comparism

Protocol	Forwarding mechanism	Loop	Route metric	Scalability	Robustness
ALARM	Directional flooding	Yes	Hops and mobility	Yes	No
Colargrosso et al.	Directional flooding	No	Hop count	No	No
DREAM	Flooding	No	Hop count	No	No
GLR	Source routing	Yes	SP	Yes	No
GPSR	Greedy flooding	Yes	SP	Yes	No
LAKER	Directional flooding	No	Hop count	No	No
LAR	Directional flooding	No	Hop count	No	No
MER	Greedy geographic forwarding	No	Maximum expectation	No	Yes
OGPR	Source routing	Yes	SP	Yes	Yes
REGR	Directional flooding	Yes	SP	Yes	No
SOLAR	Greedy geographic forwarding	No	SP	No	No

Table Key:
Route Metric SP = shortest path; LSP = local shortest path; WDG = weighted distance gain; CC = communication complexity; H = high; M = medium; L = low.

4.0 COMPARISM OF SIMULATORS OFFERING VARIOUS PROTOCOLS BY DEFAULT

Simulators have helped researchers to simulate a protocols and observe its behavior with changes to certain network metrics and variable. There are numerous network simulators available for use. Some of these simulator area free to use, some are open source while others can be used with paid license. The Comparism of simulators as listed by [2] and their various default protocols were surveyed in the table below.

Table 10. Comparison based on O. S. platform, license and MANET protocols supported

Simulators	Operating System Supported	Programming Language	GUI Support	Support Service / Documentation	MANET Protocols	License
GloMoSim	Linux, Windows	C / Parsec	Poor GUI Support	Poor	Fisheye, DSR, DSDV, WRP, LAR, DREAM, NS-DSDV	Open Source
JiST/SWANS	Linux, Mac OS, Windows	Java/Tel	Poor GUI Support	Fair	ZRP,AODV,DSR	Open Source
J-Sim.	Linux, Mac OS, Windows	Java	Poor GUI Support	Fair	DSR, AODV	Open Source
MATLAB / Simulink	Linux, Mac OS, Windows	C++ / MATHLAB	Excellent GUI	Excellent	Routing Protocols generally for all Ad hoc Network	Commercial
NetSim	Windows	C / Java	Excellent GUI	Excellent	AODV, DSR, OLSR, ZRP	Commercial

Ns2	Linux, Mac OS	C++ / OTcl	Poor GUI (Command Line)	Poor	DSR,AODV,DSDV	Open Source
Ns3	Linux, Mac OS	C++ / Python	Poor GUI (Command Line)	Good	OSLR,AODV, DSR,DSDV	Open Source
OMNeT++	Linux, Mac OS, Windows	C++ / NED	Good GUI	Good	OSPF,BGP	Freeware
OPNET	Linux, Windows	C++	Excellent GUI			Commercial
QualNet	Linux, Mac OS, Windows	Parsec	Excellent GUI	Good	Fisheye, DSR, DSDV, WRP, LAR, AODV	Commercial

From the table above, a lot of protocols are not supported by default by these simulators. Researcher have to hard code this protocols in their various programming languages (C/C++, Java, NED, Python). This would definitely increase research time.

5.0 CONCLUSION

5.1. Conclusion

Various MANET protocols have been listed and discussed above. Protocols under the category of proactive, reactive and hybrid were x-rayed. Other protocols with specials features like the hierarchical, power-aware, location-aware protocols, etc. were highlighted in this review. Also Developers of Network Simulator should implement most of these protocols highlighted in this study to enable researcher have a handful of protocols to experiment with. This will result to an increase in novel protocols entering the space. Simulations tools like OPNET, QualNet, NetSim, JiST/SWANS and NS-3 simulators should increase the number of MANET protocols in their protocol repository.

5.2. Gaps for future research

Researchers should study on more ways to address the following issues that are of concern to the MANET:

1. Mobility issues that result to loss of packet in routing.
2. Effort should be made to create hybrid protocols that will leverage the positives from the proactive and the reactive protocols towards solving issues currently encountered in routing.
3. Due to the mobility of nodes, more power-ware protocols should be researched to minimized power in nodes.
4. Creation of new network simulator to address MANET protocols. This will result to an increase in novel protocols entering the space.
5. Finally, researcher should as well see ways of using artificial intelligence, machine learning and deep learning techniques to see to optimal path or shortest path can be selected for routing in MANETs.
6. Security of MANET protocols should be also researched.
7. Efficiency over multimedia routing.
8. Finally, researcher should as well see ways of using artificial intelligence, machine learning and deep learning techniques to see to optimal path or shortest path can be selected for routing in MANETs.

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