Mobile Ad Hoc Network in Disaster Area Network Scenario

A Review on Routing Protocols

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Abstract—Disasters could cause communication systems to partially or completely down. In such a case, relief operations need a rapidly deployed communication system to save lives. Exchanging information among the rescue team is a vital factor to make important decisions. Communication system required to be robust to failures, rapidly deployable, easily maintainable to provide better services. Wireless ad-hoc networks could be the choice of establishing communication with the aid of existing infrastructure in a post-disaster case. To optimize mobile ad-hoc network performance, address the challenges that could lead to unreliable performance is required. One and the most crucial key challenge is routing information from a sender to a receiver. Due to the characteristics of a disaster environment such as signal attenuation, communication links exist between rescue crew is short-lived, suffer from frequent route breakage, and may result in unreliable end-to-end services. Many routing protocols have been proposed and evaluated in different network environments. This paper presents the basic taxonomy of Mobile Ad Hoc Networks and the state of the art in routing categorizes (Proactive, Reactive, Geographic-aware and Delay tolerant Networks (DTN)). The comparison of existing routing protocols in Mobile Ad-Hoc Networks indicates that overhead in Proactive and Geographic is competitive with delay in Reactive and DTN routing.

Keywords—MANET, Routing, Disaster Scenario, Proactive, Reactive, Geographic-aware and Delay Tolerant Networks

1 Introduction

A disaster while if it is natural or manmade creates an area in emergence needs for food, medical demands, and rescue operations. Usually, it is impractical to rely on previously installed networks to offer these services as it suffered from partial/complete distortion. Therefore, a need for an emergence network with special characteristics arises. Characteristics such as portable, scalable, wireless, infrastructure-less, and immediate installation and deployment. Communication of unlimited collection of devices in peer-to-peer fashion, infrastructure-less, self-organizing, self-configuring, wirelessly, and spontaneously known as Ad hoc network that refers to as a Latin word means “for this special purpose” [1][2]. Ad Hoc Network concludes wireless sensor network (WSN) that constructed of many mini, cheap and simple sensor nodes spread on a large area to collect environmental information and send them to a static base station in a single-hop fashion which in turn process and analyze the received data [3]. Vehicular ad hoc network (VANET) has the concept of establishing a network of cars and with fixed Road Side Units for a specific need or situation [4][5]. Mobile Ad Hoc Network (MANET) is considered a multi-hop heterogeneous network. Nodes in MANET act as routers and as end-system nodes spontaneously. MANET is self-organized, no need for external network set-up (it is a self-configured network), provides the ability to construct a temporary network, and allows nodes to communicate with each other easily [6].

MANET has applications in military and civilian pitches, both necessitate MANET's significant application [7]. It is of crucial importance to have the ability to communicate among the military nodes in a hostile area where there is no previously installed network. Besides, a collection of diverse nodes could communicate in a trip, conference, taxi network, meeting rooms, sports stadiums, boats, small aircraft, or in emergency conditions, for example, a disaster recovery, fire, or earthquake without any infrastructure installation [8]. In this paper, we illustrated a comparison of the MANET routing protocol characteristics. Besides, a systematic and comprehensive review was performed of the most recent proposed methods in four categories of routing protocols of the MANET in DTN.

The rest of the paper is organized as follows: An overview of MANET characteristics and protocols theories are presented in Section 2, while section 3 provides a review of some selected MANET routing protocols and emphasis on protocols that have been proposed recently, furthermore, classify them into four classes: proactive, reactive, geographic and DTN routing protocols. In Section 4, the challenges inherent in the routing task in the disaster area are described briefly. Section 5 analyzes the previously described routing protocols and assess the experimental results of routing in several various scenarios. Section 6 summarizes and concludes the paper with some recommendations for future research directions.

2 An Overview on MANET

Mobile Ad-hoc Network (MANET) is a self-organized and decentralized network. Nodes in MANET are autonomous and connected via wireless links. MANET's main characteristic is the continuing mobility of nodes which could result in frequent topology changes that lead to many challenges such as route data packets between nodes. MANET could be employed in various environments to rapidly establish and easy to use the network, MANET environments including Vehicular Ad-hoc Network (VANET), Wireless Sensor Network (WSN), and Disaster environment, each environment has unique characteristics compared with others, for instance, VANET node follows predefined routes at high velocity which makes its mobility pattern different compared with WSN nodes that have fixed positions with a limited energy source.

MANET network suffers from many challenges such as low bandwidth, high power consumption, low memory, processing limitation and mobility pattern changes since nodes in MANET are various in transmission range and have limited power resource that cannot be recharged or replaced usually [9] [10] such as mobile phones, PDA, Digital Cameras, earphone, wristwatch, iPad or laptop. Mobility pattern challenge leads to frequent changes in the network topology. Unlike Wireline networks, the wireless connection is different due to interfering, intra-flow, inter-flow, fade problems. Nodes communicate with each other in peer-to-peer requests in the absence of a centralized node. Therefore, data need to be forwarded via intermediate nodes, introducing routing as a key challenge in a mobile ad hoc network. MANET with such characteristics meet most of the requirements of disaster area scenario, therefore, emphasis on routing in MANET: presenting routing protocols principles, pros, and cons to displaying their suitability's in calamity scenarios.

Routing can be defined as a process of establishing a route from the sender node to the receiver node. Upon the absence of centralized control node, each sender node sends data packets to the destination node directly if they both in range. Otherwise, the routing protocol should forward packets through intermediate nodes to reach the destination node. Nodes mobility creates and breaks links frequently results in building /degrading paths each time subsequently finding a specific path is a critical issue [11][12][13]. Some routing protocols require nodes to be familiar with their neighbors using diverse techniques, for example, Multicast and broadcast. Such techniques result in another challenge which is a multi-cast tree and load balancing [14][8]. Upon dynamic topology and diverse transmission range, a network-partitioning problem appears. Hence, it is indispensable to detect the critical links/nodes, which their failure causes network partitioning periodically, reduces packets loss as well as route discovery time [15]. In general, the routing protocols function is to build a reliable route from a sender node to a destination [16]. These protocols could be broadly classified into four classes as follows: Proactive Routing Protocols, Reactive Routing Protocols, Geographic Routing Protocols, and Delay Tolerant Network Protocols (DTN). Figure 1 illustrates the considered classification of MANET routing protocols in this paper.

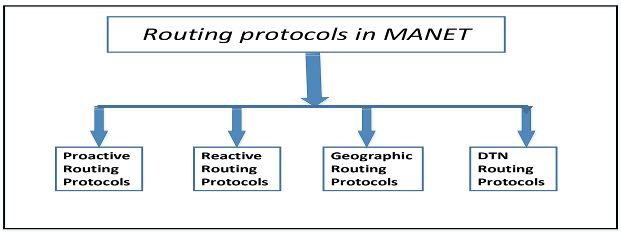

Fig. 1. Routing Protocols Categorization

This paper considers two of the most well-known protocols from each category and summarizes their characteristics as shown in Table1. The following section provides a brief description of the routing classes.

2.1 Proactive routing protocols (Table-driven)

The routing information in proactive protocols is maintained and stored in routing tables. Nodes update its routing tables periodically by broadcasting it to all nodes in the network via routing messages [17][18]. Destination Sequenced Distance Vector Routing Protocol (DSDV) and Optimized Link State Routing Protocol (OLSR) are examples of proactive routing. The following sub-section explains DSDV and OLSR.

2.2 Destination Sequenced Distance Vector routing protocol (DSDV)

Perkins and Bhagwat proposed a relatively new proactive routing protocol based on the classical Bellman-ford algorithm [19] that was specified by RIP [20][21]. Nodes in the network maintain a routing table of its neighbors and frequently send it to its neighbors [22][23]. To avoid routing loops (count to infinity), the main drawback in the bellman-ford algorithm [24], DSDV make use of sequence number [25][26] in addition to the destination address and hops count for each entry in the routing table to distinguish among the stale and fresh routes [27][28][29]in the routing table, see table 1. Updating the routing table is done by utilizing two types of routing packets, firstly, full dump (carry all the available information) and incremental update (upon any significant topology change) routing packets [30][31]. Thus, there will be two routing tables kept at each mobile host. The first one is for use with progressing packets and the second table is to be advertised via incremental packets [20].

Optimized Link State Routing Protocol (OLSR): Jaquet et al. in 2001, presented a link-state protocol that is table-driven, proactive in nature named optimized link state as its un blind flooding mechanism feature [32]. Nodes with OLSR exchange topology information periodically depending on some selected nodes called multipoint relays (MPRs) as shown in fig. 2 [33]. trying to providing optimal routes in terms of hop-count metric [34][35] employing three types of control messages: firstly, HELLO-messages, by performing local link sensing, neighbor detection up to 2-hop neighbors to build its own neighbor table [36]. Secondly, Topology Control messages (TC-messages) to perform the task of topology declaration (advertisement of link status) [37], as illustrated in Table 1. Lastly, the Multiple Interface Declaration (MID-messages), for nodes that have multiple interfaces [38].

OLSR makes use of IP4 addressing, un-dependable on link layer protocol, and supports multiple interfaces for a single node that one interface can participate in MANET and others could join any other network [39]. TC messages can only be headlong by the MPR nodes all over the network [40][41].

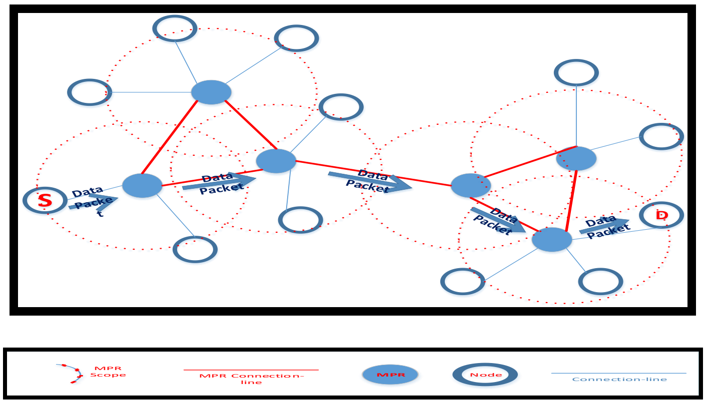

Fig. 2. OLSR MPRs concept

2.3 Reactive (On-demand) or distributed routing protocols

Another class of routing protocol is Reactive routing. In this category, the path is built when the sender nodes wish to transmit data to the receiver. The source node needs to broadcast a route request packet to the whole network. Nodes who received a request packet (not a destination node) will perform a re-broadcast of the requested route packet to neighboring nodes. This process continues until the desired destination is found. When the destination node receives a path request message (or intermediate-route nodes know a path to the destination), the node replies to the sender node [42]. Whenever a source node required transmitting data packets towards a destination, it floods the network with route request packets. The destination sends a route reply message in a unicast manner, then the source node transmits the data packet to the destination node. Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector Routing (AODV), and Temporally Ordered Routing Algorithm Protocol (TORA) protocols are examples of reactive routing protocols.

Ad hoc On-demand Distance Vector routing (AODV): AODV is a distance vector routing protocol for MANE proposed in 2003 [43]. AODV is designed to cope with high-density network topologies and under various velocities. It has been designed to operate in trust networks that could not include malicious nodes in a loop-free manner, avoiding counting to infinity problem associated with classical distance vector protocols [43][44]. There are two operating modes in the AODV routing protocol, route discovery and route maintenance [45]. AODV control messages can be defined as Route Requests (RREQs), Route Replies (RREPs), Route Errors (RERRs), and Route Reply Acknowledgment (RREP-ACK). Routes are initiated only on request [46]. With AODV, the source node establishes a route to an unknown destination when there are data packets that need to be sent. Path construction is achieved by broadcasting a Route Requests (RREQs) message to its neighbors maintaining an incremental (fresh) sequence number to preserve updated information as shown in fig. 3 [45]. The intermediate node receives a request and look-up in its routing table for a route to the desired destination. Due to the result, it may reply to the origin node with the full route via Route Replies (RREPs) in unicast mode or rebroadcast message till received by destination node [46]. Based on receiving the RREP, the sender node sends (RREP-ACK) message to the target node informing it that it is going to use this route to guarantee bi-directional link [43] See table 1. [47] [48]. Due to node mobility and limited battery power of mobile nodes, network topology changes cause link failure ensuring the need for route maintenance [47]. Each node losses a link to the destination node, need to send a (RERR) message to neighbors to inform them that the current using route is no longer valid and it may operate a local repair as illustrated in fig. 4.

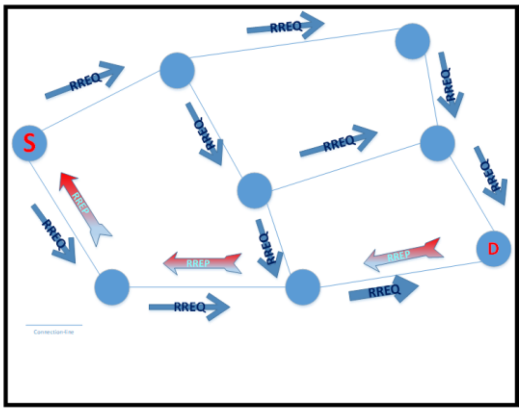

Fig. 3. AODV Route Discovery

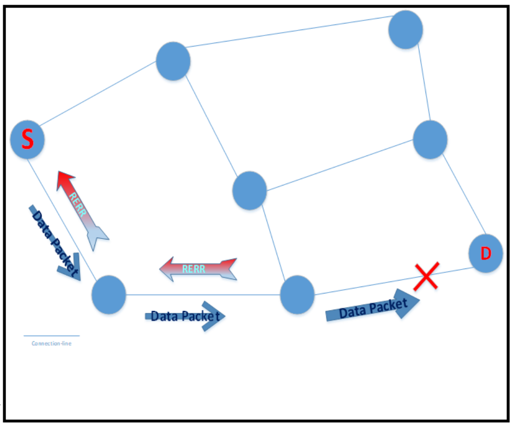

Fig. 4. AODV Route Discovery maintenance

Dynamic Source Routing protocol (DSR): DSR is an on-demand protocol first proposed in 1994. It has two stages route discovery and route maintenance just like AODV. But, with different mechanisms allowing multiple routes to any destination, ensuring loop-free routing in a network up to (200) nodes density and high rates of mobility. Unlike AODV operation, DSR supports unidirectional links, see table 1 [49]. This protocol is named source routing due to the header of the data packet which carries itself complete routing information to reach the destination node [50]. Again, unlike AODV, there is no need for any periodic updating to ensure connectivity among neighbors [51]. Upon any active link failure, a route error packet (RERR) is produced and forwarded back to the source node [52]. Any node who overhears RERR removes route(s) containing a broken link from its routing table [53] [54] [55]. A route cache in each node has to be maintained, it is containing source routes that it is aware of. On one hand, the DSR routing scheme, apply flood mechanism in RREQ initiation that is considerable energy waste and network overhead increase. In another hand, route cache information is used effectively by intermediate nodes for lowering control overhead. Intermediate nodes learn via overhearing meanwhile they forward data packets or RREPs that result in overhead minimization. Node energy is the most critical resource to conserve. Conserving node energy in active and inactive mode could be achieved in DSR by utilizing energy-efficient approaches in Transmission power control, Load distribution, and Power-down or sleep mode [56]. Since DSR produce multiple paths and act in an on-demand manner. When a link between two nodes breaks, a node that detects failure sends a Route Error (RERR) packet to a sender node to update its route cache as well as all nodes that overhear and forward the message. The source node can employ an alternative path to the destination stored in its cache or initiate a new route discovery mechanism to build a new route [57]. Hop count metrics are applied in DSR to opt for the shortest path between the sender and receiver [58]. Mainly, DSR offered to adopt at link layer [50].

2.4 Geographic routing protocols in MANET

In routing, the goal is to locate the destination node and determines forwarding nodes to it based on their physical location information. In this category, the node needs to be aware of its location as well as the location of the destination. Greedy and face principles are majorly used. Well-known examples of Geographic routing are the Greedy Perimeter Stateless Routing (GPSR) protocol and Zone Routing Protocol (ZRP). The following subsections explain how GPSR and ZRP maintain the routing process.

Greedy Perimeter Stateless Routing (GPSR): Karp and Kung in 2000 [59], presented a novel geographical routing protocol that assumed that each node knows its location as well as its one-hop neighbors using GPS or any other techniques. It utilized two techniques to forward the packet: greedy and perimeter, see table 1. Greedy forwarding was applied initially as much as possible. Node forward packet to a neighbor that is close by destination node as shown in fig. 5. The greedy principle is to forward the data packet to a neighbor if and only if it is closer than itself to the destination node. Therefore, this approach does not guarantee the delivery of data packets if the packet faces a void node. The void node can be defined as a node with no neighbors closer to the destination node than itself.

In case of greedy techniques failure that is when a node like A has no neighbors nearest of itself to the destination node. The protocol switches to the perimeters principle to continue forwarding the packet to its perimeter neighbor nodes to find its way to the desired destination as shown in fig. 6.

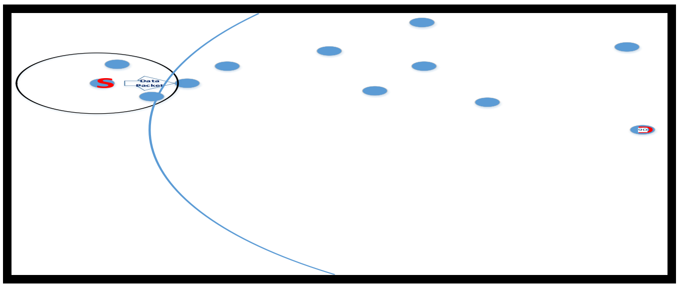

Fig. 5. Greedy forwarding

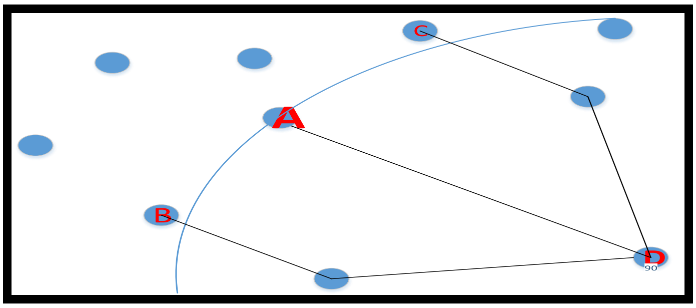

Fig. 6. A is the void node

Zone Routing Protocol (ZRP): ZRP is not an independent protocol but it could be considered as a routing framework due to its architecture [60]. It divides the network into overlapped zones keeping routing in flat style, each node surrounded by a scope of predefined radius to deliver packets in a proactive manner utilizing intrA-Zone Routing Protocol (IARP) within zone [61]. Meanwhile, using the Inter-Zone Routing Protocol (IERP) whenever the destination node is not in the local zone in reactive style [62]. ZRP uses "hello" beacons to discover new neighbors. In each zone, nodes having a distance less to a pre-defined radius called interior nodes and peripheral nodes are those nodes having a predefined radius of scope. Source node multicasts request to all nodes in its zone [63]. Node with the route to destination could reply to the query. Otherwise, peripheral nodes utilizing Bordercast Resolution Protocol (BDP) establish a route discovery mechanism that could be achieved by either Root-Directed Bordercasting (RDB) [64], see table 1. Source node builds a multicast tree and adds routing information to packet or Distributed Bordercasting that each node reconstructs tree [65]. The zone radius is defined as several hops from the central node (zone owner) to the perimeter of the zone [66][67]. In the case of link failure/link broken, corresponding packets could be transmitted by bypassed over border nodes to reach its destination in case link failure is within zone [68]. Otherwise, link maintenance has to be established [60]. ZRP with proactive style in local area network goal of communication with lass delay that can be discarded more over utilizing local topology information in inter-zone communication. Hence, it outperforms other pure reactive protocols (in delay time) remaining an important inquiry about the radius value of zones to be adjusted adaptively to each network privacy.

2.5 Delay Tolerant Network (DTN) in MANET

Delay-tolerant networks were firstly introduced in 2003. In MANET, the path duration between source and destination at a given time is short. Therefore, the network could be unpredictable in terms of performance due to the dynamic nature of network topology. Delay and disruption tolerant networks suffered from a lack of connectivity between nodes in the network, resulting in a lack of instantaneous end-to-end routes. In such unstable environments, conventional ad hoc routing protocols reactive/proactive could not provide sustainable end-to-end paths. As these protocols, establish a complete route to destination then forward the actual data packets. DTN copes with such a challenging environment by employing a "store and forward" approach, where data incrementally moved and stored throughout the network in hopes that it will eventually reach its destination. In DTN, a new layer introduced named 'Bundle layer' in the architecture, it is located between the transport layer and application layer used for store and forward messages [69]. However, in case of a lack of routes to the destination, a message is stored and carried until a new route becomes available. Messages are removed from the buffer when the lifetime expires or for buffer management reasons. To maximize the probability of messages being successfully delivered to the destination, intermediate nodes transmit redundant copies of messages assuming at least one copy will successfully reach its destination. DTN Protocols suffer from long or variable delay, asymmetric data rate, high error rates, and poor security.

Researchers proposed many classification theories on routing in DTN. The most common techniques in DTN routing are based on replicating messages and considered replication/flooding-based [70]. On the other hand, DTN protocols that do not replicate a message considered forwarding-based protocols. Both routing techniques have their pros and cons, considering one and leaving others depending on the given scenario. The forwarding-based DTN Protocols suffered from a low delivery rate due to the only one copy of the message available in the network trying to reach the desired destination. Hence, conserving the limited network resources, while replication-based DTN Protocols consumes network resources by transmitting many copies of a message trying to achieve a high delivery rate. Spray and Wait [71], PROPHET [72], and RAPID are examples of replication-based DTN Protocols. Although, Delay-Tolerant Link State Routing (DTLSR), Schedule-Aware Bundle Routing, Contact Graph Routing, and Non-cooperative Routing in Delay-Tolerant Networks are examples of forwarding-based DTN Protocols.

Epidemic Routing (Replication / Flooding based): In Epidemic routing, nodes record receiving messages information and store it in a summary vector. Upon receiving the message, the node replicates the message to every other node it met. If the node did not receive a message copy before (by lookup in its summary vector), message replication is done by placing an upper bound on message hop count and per-node buffer space [70] [73]. Any two nodes exchange their summery vector any time they communicate, see table1. Nodes compare their summary vector and transmit the messages, which they do not have. Epidemic routing tries to find the optimal path; however, it consumes resources such as buffer and bandwidth [69].

Delay-Tolerant Link State Routing (DTLSR): DTLSR build paths by utilizing link-state knowledge depending on network topology information stored in each node [74]. Routes established as in classic link state approaches as can be shown in Table1. Node operates on a separate area as a link-state. Nodes with neighbors that located in different areas declare themselves as a gateway to endpoint identifiers if they learn of those end-point identifiers reachable via other areas [74]. In [75], the authors proposed an improved version of the DTLSR protocol to enhance operation in hierarchical network topologies utilizing IS-IS routing [76].

Table 1. A comparison of Addressed MANET Protocols Characteristics [77]

Protocol	**AODV [43]**	**DSR [50]**	**DSDV [20]**	**OLSR [32]**	**ZRP [60]**	**GPSR [59]**	**Epdemic [73]**	**DTLSR [74][78]**
Protocol principle	Distance vector, on-demand	Source routing, on-demand	Bellman-Ford routing mechanism	Link state	Geograph-ic	Geographic	DTN	DTN
Link character-istic	Bi-directional	Uni-directional	Bi-directional	Bi-directional	Uni-directional	Bi-directional	Uni-directional	Uni-direction-al
Overhead	Low	Low	High	High	Medium	Medium	High	High
Control message Ack	Required	Required	Not	Not	Required	Not	Not	Not
Request Technique	Flooding	Flooding	Full dump	Multipoint relays	Bordercast Resolution Protocol (BRP)	Greedy technique	Flooding to Carriers	Flooding within bundle layer
Provided route	Single	Multiple	Single	Single	Single	Single	None	None
Underlayer Protocol	Any link layer	Any link layer	Layer 2 or 1	Any link layer	Bordercast Resolution Protocol (BRP)	IEEE 802.11 MAC	Any link layer	Any link layer
Network dense	Tens to thousands	Up to 200	Low	Large & Dense	Large	Large	Large	Large
Mobility speed	Low, Moderate, High	Moderate	Low	High	High	High	High	Any
Topology Infor-mation	Not	Not	Required	Required	Required	Required	Not	Required

3 State of Art on MANET Routing Protocols

This section describes recent work that has been proposed on the selected MANET routing protocols. This paper considers the following evaluation metrics based on the state of art in [22] and [79].

1. Packet Delivery Ratio (PDR): It is the ratio of successfully delivered data packets to destination compared to transmitted at the sender.
2. Normalized Routing Load (NRL): number of control packets required for successful packet transmission
3. Packet Loss Ratio (PLR): It is a ratio of the total number of lost packets during transmitting in the network compared to the total number of sending packets.
4. End to End Delay (E2E Delay): The time taken by a data packet to travel from source to destination.
5. Throughput: Total of received bits in a specific time measured in kilobits
6. Jitter: the time variation among received packets.
7. Normalized MAC load: It is the number of control bits required for successful every single transmission to the destination on the MAC layer.
8. Overhead: number of control packets as bits required for each successful data packet delivery.

3.1 Proactive routing protocols

In the wireless mesh network, Fengjieet. et al. proposed Divide Cluster-DSDV and imitate the idea of Mixed Routing Protocol (ZRP) to lessen cluster head load in DC-DSDV [80]. MANET protocols performance affects by network dense that pushes authors of [81] to propose a protocol selection mechanism, among (AODV, DSR, and DSDV) protocols based upon the CBR traffic agents. Keerthiga et al. [82] proposed a design comprises SWIPT and energy-efficient DSDV protocol in cognitive WSN to reduce the spectrum absence and energy consumption. Tareq and Abed [27] proposed a model inspired by artificial bee colony (ABC) to minimize the energy consumption of the selected route and applied it on (DSDV, AODV). Results showed that AODV outperformed DSDV in term of end-to-end Delay.

Chbib et al. [37] proposed two schemes (Routing Table Mechanisms and Backup MPR). They aimed to minimize the number of executions of MPR to solve the control messages congestion problem in OLSR upon any link failure with neighbors. Harrag et al. [38] proposed NSGA-II by applying non-dominated sorting algorithm-II which is a multi-objective generic non-explicit optimization algorithm to OLSR parameters to optimize its metrics. Xie [83] enhanced OLSR to adopt ocean FANET (high nodes mobility) calculating link failure time by benefiting from GPS information and residential node energy. Al-Kharasani et al. [84] proposed a framework by using network resources. To obtain the optimal configuration of quality of service (QoS) requirements based on the competitive cost evaluated in the previous stage. In [36] an optimization in multi-Point Relays of OLSR was made to select them to left or right of source node based on destination node location that improves the metrics: overhead, throughput, Packet Delivery Ratio, and E2E Delay.

Table 2. Literature Details of Proactive Protocols

Ref.	Year	Protocol	Proposed Technique	Metrics	Application
[27]	2019	DSDV, AODV, ABC	Applied proposed ABC optimization in energy consumptions to various scenarios	E2E delay, PDR, PLR, and Average Energy Consumption	MANET
[80]	2018	DSDV	Applied Clustering in information redundancy problem for DSDV and optimize routing time link metric benefiting from AODV and ZRP hybridization	E2E delay and overhead	WMNS
[81]	2018	DSDV, DSR, AODV	Proposed a mechanism to select the most suitable protocol among other protocols based upon the CBR traffic agents	E2E Delay, throughput, PDR, DPR, overhead, and jitter	MANET
[82]	2019	DSDV	SWIPT proposed which is an energy harvesting mechanism employ DSDV to overcome power consumption problem and spectrum scarcity by reducing the number of active sensor nodes.	Energy efficiency, E2E delay, PDR, Throughput	WSN
[36]	2019	AOLSR	An optimization in Multi-Point Relays selection applied to TCP and UDP	E2E delay, PDR, Throughput, and overhead	AANET
[37]	2019	OLSR	propose two new methods (Backup MPR, Routing Table Mechanisms) to minimize the number of executions of MPR reducing congestion of control messages	PDR, Throughput, and overhead	MANET
[35]	2019	OLSR	solve scalability task by automating the selection of protocol parameters using a multi-objective genetic algorithm.	(PLR, E2E delay) in low & high mobility	MANET
[83]	2018	OLSR	use of Global Positioning System (GPS) information in node-link expiration time calculation and residual energy	Overhead, E2E delay and PDR	FANET

Where**:** PDR refer to Packet Delivery Ratio, NRL refer to Normalized Routing Load, PLR refer to Packet loss Ratio, and E2E Delay is End to End Delay

3.2 Reactive routing protocols

This approach-overcome bandwidth overhead in network problems by getting rid of unused routes as do proactive protocols. However, the main disadvantage is obtaining the necessary path usually is going to be delayed until the path is built [86]. AODV shows a gap in security just as other protocols and wider transmission limit that triggered by delay for a requested route to be constructed [87]. In the case of each node in MANET rely on the battery, this could result in link breakages and network partition problems due to batteries drain problem. Nodes could be off, after a while, the whole network could be down. Therefore, the power consumption problem is a real issue [88]. Finding a method to increase network lifetime and lessening link breakages by building paths with energy awareness could be a decent solution [48].

Researchers of [89][90][91] aimed to reduce battery consumption to increase network life proposing various techniques. Meanwhile, Benakappa and Sushmitha [91] selected nodes in the path for next-hop depending on current, wanted for transmission, and remain energy of each node. Also, Bhagyalakshmi and Dogra [92] controlled RREQ flooding to achieve the same goal. Bhattacharyya1 et al. [93] considered packet size reduction and the ratio of energy/distance. Performance improvement was achieved in [94] by employing AODV routing alongside the combination of the bee colony and ant colony to build a route to the desire destination. Thamalaka et al. [94] made use of a novel caching mechanism. Thamalaka et al. [95] Authors implemented a novel route caching mechanism for AODV protocol. Jhajj et al. [96] added multiple path characteristics to AODV as a need for congestion control and performance-enhancing. Tareq et al. [27] reduced limited resource ‘energy ‘consumption employing the searching behavior of bee colonies (ABC) based algorithm and applied their proposal on AODV and DSDV.

Pereira et al. [79] investigated DSR performance in VANET, employing a two-lane road with distributed devices scenario. They used and best disposition of relay poles, to increase network throughput, essential radio settings with the use of different channels are applied. Barve et al. [57] proposed passive clustering in the flooding stage of DSR to reduce overhead. Clusters' creation of the network was in the Route Discovery process phase to deploy a subset of nodes to receive and forward the Route Request messages. YANG et al. [97] optimized routing utilizing Continuous Hopfield Neural Network producing an optimal path in terms of most metrics. Umapathi and Ramaraj [98] optimized the original version of DSR by combining Ant Colony Optimization (ACO) and Tabu search algorithm. They aimed to discover paths to destination with an optimal-hop count, link quality, and bandwidth estimation unlike previously dependent metrics for link selection, which were hop-count. Ullah et al. [99] utilized another technique to optimize routing based on selecting paths on different constraints (energy awareness and congestion less). Prasath and Sreemathy [51] optimized DSR utilizing bio-inspired Protocol FireFly considering link quality, node mobility, and end-to-end delay. Sharma et al. [58] utilized an Adaptive Fuzzy Inference System (ANFIS) to improve the performance of the DSR protocol; they proposed a protocol named A-DSR. Ahn and Kim [100] aimed to reduce cached RREP storm problem resulted from cached Route Reply (RREP) message from nodes had routes to the destination. They employed an adaptive generates mechanism to cached RREP messages according to the network situation.

Table 3. Literature Details for Reactive Routing Protocols

Ref.	Year	Protocol	Proposed Technique	Metrics	Application
[3]	2017	Ant Colony	Energy optimization approach applied to select the path relying on residential energy	Energy consumption	WSN
[6]	2018	AODV	Proposed an approach to detecting and eliminating black holes (DEBH) by using a data control packet and black hole check.	Delay, Overhead, Throughput	MANET
[15]	2018	DHT	Proposed a protocol for partitioning issue by employs pre-partitioning measures	Delay, Overhead, success ratio	(DHT)-based MANET
[45]	2016	AODV	Analyze black hole, flooding, and rushing attacks	PDR, Delay, Throughput	MANET
[47]	2018	AODV	Hybridization of applying Dijkstra Algorithm on AODV	PDR, Queueing Delay	MANET
[48]	2019	AODV	The Proposal was to select paths by sources or intermediate nodes based on residual energy (energy-efficient approach).	PDR, Bandwidth utilization, PLR, Overhead	MANET
[88]	2016	AODV	Investigation & Analyze of AODV from Energy view	PDR, throughput	MANET
[51]	2018	DSR	performance of (DSR) is investigated. DSR is modified utilizing the Firefly algorithm to find optimal paths	Throughput, E2E Delay, Number of hops to the destination, and Number of retransmitted packets	MANET
[57]	2016	DSR	proposed algorithm based on DSR protocol that integrates Passive Clustering.	Overhead, PDR	MANET
[58]	2019	DSR	A-DSR is proposed to select the optimal path by employing an adaptive fuzzy inference system (ANFIS)/	PDR, E2E Delay	MANET
[97]	2017	DSR	Continuous Hopfield Neural Network is used to find an optimal or nearly-optimal route.	Throughput, E2E Delay and control overhead	MANET
[98]	2017	DSR	hybrid optimization based on DSR, Ant Colony Optimization (ACO), and Tabu search to find routes to destination with the optimal-hop count, link quality, and bandwidth estimation	PDR, E2E Delay	MANET
[79]	2018	DSR	Evaluate the Dynamic Source Routing (DSR) algorithm for VANETs	Normalized MAC load, Normalized routing load Overhead, PDR, PLR	VANET
[100]	2017	DSR	propose an approach that adaptively generates cached RREP messages according to the network situation	Overhead	MANET
[91]	2018	AODV	The authors proposed a protocol based on the remaining and future energy level of nodes. The protocols consider nodes with the lowest need for energy and greater remaining energy as intermediate hops.	Throughput, PDR and energy consumption	MANET

[92]	2018	AODV	The authors proposed an approach that controls the route request (RREQ) broadcast storm by using the node's queue length. Source appends a random number with RREQ which is compared with the queue length at each intermediate node.	Enhancing QoS in terms of E2E delay, throughput, and jitter	MANET
[93]	2018	AODV	A protocol to reduce energy consumption in each packet transmission by reducing packet size and maintain an 'Energy/Distance' ratio as a metric for tracking the best route	Analytically reduce overhead	MANET
[94]	2017	AODV	A protocol inspired by hybridization of Ant, Bee, and AODV	E2E Delay, PLR, and throughput	MANET
[95]	2018	AODV	modified protocol repairs route failure using cached routes	throughput, E2E Delay and PDR	MANET
[96]	2019	AODV	proposes an Efficient Multipath AODV routing algorithm	throughput, E2E Delay PLR, and PDR	MANET

Where: PDR refer to Packet Delivery Ratio, NRL refer to Normalized Routing Load, PLR refer to Packet loss Ratio, and E2E Delay refer to End to End Delay

3.3 Geographic routing protocols

Bala and Krishna [101] performed a detailed investigation scenario based on GPSR Protocol performance in VANET and compare it to the AODV protocol. Moreover, the authors tried to improve both performances by using IEEE 802.11p instead of IEEE 802.11. Al-shugran et al. [102] substitute proactive periodic update of location information for one-hop neighbors by Dynamic Fuzzy Logic Controller and Mobility Prediction (DBUM) resulting in overhead reeducation. To overcome redundancy in perimeter forwarding in VANET particularly in first-hop neighbors, Yang et al. [103] substitute greedy forwarding by Maxduration-Minangle GPSR. Next hop selected based on higher cumulative communication duration among neighbors, in perimeter concept; make use of minimum angle as next hop. Sun et al. [104] proposed an algorithm to speed up GPSR Protocol considering energy consumption in evaluating potential next hop. Yang et al. [105] utilized Link Available Time (LAT) prediction to select the next-hop instead of the blind greedy principle. Walker and Radenkovic [106] proposed a system that permits vehicles to request and receive live video from vehicles within a select physical section. Yang et al. [107] presented an improvement to ZRP adding clustering concept in the VANET environment. While Malwe et al. [61] improvement was selective border-cast of peripheral nodes and previous destination location information based on connectivity and network density. Authors of [85][108] enhanced ZRP utilizing Adaption of zone radius notion based on PSO algorithm and Fuzzy principle respectively. Oigawa and Sato [109] employed topology information alongside Bloom filters to improve ZRP performance. Ghode and Bhoyar proposed an ahead selection process based on residential node energy in the zone. Ghode and Bhoyar [110] proposed the Node Energy Monitoring Algorithm (NEMA) to monitor changes in the energy level of nodes and select the cluster head node based on their energy.

Table 4. Literature Details of Geographic Routing Protocols

Ref.	Year	Protocol	Proposed Technique	Metrics	Application
[101]	2015	GPSR	Performance improved by using IEEE 802.11p instead of IEEE 802.11.	PDR, E2E Delay	VANET
[102]	2018	GPSR	Apply fuzzy logic controller and Mobility Prediction algorithm	Overhead	MANET
[103]	2017	GPSR	Proposed Maxduration-Minangle GPSR (MM-GPSR) routing protocol	Overhead	VANET
[104]	2017	GPSR	Proposed SU-GPSR Protocol that involved both still nodes and mobile nodes	Energy consumption, PDR, E2E Delay,	WSN
[105]	2017	GPSR	Established a matrix based on the LAT and geographic progress of neighbors' nodes to make next-hop decision	Average delay, PDR	VANET
[106]	2017	GPSR	Presented a system offering multi live video streaming	PDR, Delay	VANET
[61]	2016	ZRP	Based on connectivity and network density presented a selective border-cast node to optimize the proactiveness within the zone	overhead	MANET
[107]	2018	ZRP	Enhancing ZRP utilizing clustering algorithm	E2E Delay, Overhead, PDR	VANET
[85]	2017	ZRP	Adaption of zone radius based on PSO algorithm	E2E Delay, Overhead, PDR, QoS	MANET
[109]	2016	ZRP	Presented bloom filter in IntErzone Routing Protocol (IERP) of ZRP	Number of Route Query packets	MANET
[110]	2016	ZRP	Use Max-heap tree concept to select maximum residual power node as Zone-head	Energy conservation	MANET
[108]	2019	ZRP	Adaption of zone radius based on Fuzzy Logic concept	Overhead, PDR	MANET

3.4 Delay tolerant network

Many investigations, issues, comparisons, and enhancements were carried out on the original Epidemic routing algorithm such as prioritized epidemic and immunity-based epidemic [78][111]. Mao et al.[112] calculated the delivery of data packets predictability according to the encountering frequency among nodes. Karimi and Darmani [113] presented a power-aware approach based on Epidemic Protocol that calculates transmission probability according to a specific time related to the node. Bialon and Graffi [114] suggested a congestion problem solution by calculating a message based probability decision depending on ephemeral information of a nodes' surroundings. Sati et al. [115] proposed the Degree and Contact Epidemic (DC-Epidemic) protocol, which copy and forward packets only when the number of neighbors equal to a certain previously calculated threshold. Threshold value calculated based on the maximum degree of contact probability values of the system. Garg et al. [116] proposed routing decisions based on battery energy level and buffer space consideration. Katti and Lilja [117] proposed a scalable system algorithm and efficient memory failure detection.

Table 5. Literature Details of Delay Tolerant Network Protocols

Ref.	Year	Protocol	Proposed Technique	Metrics	Application
[112]	2019	PROPHET	Two scheduling mechanisms are proposed to improve storage and transmission performance in DTN.	Buffer size with Delivery Rate, Delivery Delay, Overhead, Hop Counts, Dropped Packets	Internet of Things
[113]	2019	Epidemic	An approach that sets transmission probability for each node based on a specific time.	Message delivery probability and the number of transmissions in the network	Heterogeneous DTNs
[114]	2019	Epidemic	An approach for congestion control utilizing nodes ephemeral information	PDR, overhead ratio, Average E2E delay, and hop-count	Opportunistic Networks
[115]	2018	Epidemic	An energy-aware routing scheme for enhancing Epidemic	Delivery ratio and overhead	Opportunistic Networks
[116]	2018	Epidemic	AN approach considering buffer space and power of forwarding nodes	Delivery ratio and traffic	DTN
[117]	2018	Epidemic	Consensus detection technique	Logarithmic scalability for failures	Extreme-scale systems with reliable networks

4 Challenges in MANET Routing

Although the MANET network has numerous advantages such as self-configuration, easy deployment, and nodes mobility. MANET has many limitations including devices is powered by portable batteries, limited bandwidth, memory, and low processing resources. Routing packets in such a highly dynamic and rapidly changing topology is the main challenge. In absence of a central control unit, a packet needs to find a reliable path throughout intermediate nodes from its source to destination. Nodes mobility as well as limited power resources resulting in link breakages and network partition problems. Hence, increasing the transmission range of nodes causes more connectivity/paths but also more power-draining, therefore a suitable balance is required. The disaster area scenario is characterized by mobility patterns of nodes, the velocity of nodes, the number of involved nodes, nodes various wireless scope in one hand. On the other hand, disaster area size, if the area has obstacles that affect transmission signal and their characteristics, type of disaster (fire, earthquake or flooding), and weather conditions, all these factors involved in routing protocol selection. A protocol that seems to work perfectly in some scenarios may not be a suitable selection for another scenario. Therefore, an area required a scenario that has to be studied and evaluated for network routing protocol choice.

5 Discussion

A table-driven protocol could be more reliable in a disaster scenario than a link-state one, given that routes were designed and ready to use before they were requested. In addition, due to having two routing tables (more memory allocation) in each node and retaining them (CPU usage i.e., energy consumption), DSDV could suffer from high energy consumption. Also, when there is no data to be transmitted, these routing packets kept updating periodically draining the node's battery. The only technique in route discovery tasks is flooding, from the DSDV protocol literacy. From this stage, OLSR imitates the transfer of control packets between neighbors and flooding constraints to some pre-defined nodes as multiple network relay nodes. This led to a major reduction in the overhead load that renders the proactivity of this protocol an additional operation. Therefore, in a disaster case, OLSR seems to be a suitable protocol since it has ready routes with low overhead and does not generate any extra control messages for link failure. Moreover, OLSR does not require any reliable transmission for its control massage since all messages contain a sequence number. Each data packet route hop by hop upon the most recently available information. The only probable con is the amount of power-draining due to different types of control messages functioning that open promising scope for power-aware routing attributes. This type of protocol is more suitable to deal with in such an area.

As a critical issue in such a network is to prolong network life, [82] authors minimize active sensor nodes number and classify them to primary/ mobile and secondary/ static nodes technique meanwhile [80] authors modify cluster algorithm to reduce the burden of the cluster header and the time required to replace cluster header node. Standard OLSR developed based on differential evolution and non-dominated sorting genetic algorithm in [35] and shows superior performance in terms of the loss ratio and end to end delay.[83] authors enhanced OLSR protocol in FANET benefiting from Global Positioning System (GPS) information to calculate node-link validation time and path nodes energy.

Relative to the Reactive principle, although DSR has many advantages over AODV like overhearing and the absence of a “hello” message. However, DSR has many weak points such as flood network with RREQ packet, and delay duration caused by route discovery that could result in burst and farther more producing congestion in high activity. In addition, it suffers from the heavy header in the situation of a long route neglecting nodes' power. The key problem in Reactive categorize is the meantime to build paths from source to destination as requested, [47] authors enhance AODV utilizing Dijkstra algorithm to find the shortest route improving Quality of Service (QoS), this results in floating another issue which is the energy consumption of repeated paths nodes that [48] authors present energy-aware routing by selecting forwarding nodes from source /intermediate nodes considering resident nodes energy. Since Standard DSR selects paths based on hop count, [58] authors develop the selection parts algorithm to rely on hop count, energy, and delay parameters to select the optimal route from the cache of nodes uses adaptive fuzzy inference system (ANFIS). As an optimization technique, [97] authors make use of continuous Hopfield Neural Networks to obtain an optimal route

Geographic routing protocols probably scale better in MANET as low overhead results from the absence of routing tables and undesirable messages exchange to monitor topology changes. Searching for forwarding nodes could be reduced by employing a Global-positioning system (GPS). A reliable and robust routing protocol should provide a high delivery ratio and fulfill application requirements.

Standard ZRP was modified by applying a clustering algorithm by [107] authors that each cluster has a single head node and usually multiple gateway nodes. Utilizing energy and speed of nodes as input parameters in applying the fuzzy logic approach to ZRP protocol to calculate radius value was presented by [108] authors and enhance network performance. Regarding GPSR protocol, Researchers present various techniques for example [102] researchers modify standard GPSR by predict nodes movements and use this information as input to the Fuzzy logic controller. Researchers in [105] enhance the blind greedy principle in GPSR based on grantee link available for the next hope utilizing geographic node location.

DTN originally proposed for Interplanetary Networks (IPNs) to provide communication between satellites and base stations. Therefore, DTNs permit information sharing between nodes despite the fact some network environments experience high delays as well as delivery ratio, which is considered normal in spatial communications [118]. This characteristic is suitable for disaster conditions in case of the wide affected area with few rescue team members ensuring delivery of all messages without lost/drop.

Epidemic protocol based on flooding principle results in overload dense opportunistic network and causes traffic congestion that is the factor to push researchers in [114] to construct forwarding decision depending on the calculated probability value per packet in congested local area meanwhile this probability information used to be updated dynamically. Another research [115] adopt an Epidemic protocol to restrict messages copies in the opportunistic network due to dynamically updated threshold depending on degree and contact as threshold = f (Dm, C%) according to a maximum degree (Dm) of all nodes and contact portability (C%) to grantee energy conservation.

In this paper, after reviewing many studies related to routing protocols to consider their adoption in the disaster area. We have come out with the comparative study shown in Table1 that summarizes their characteristics. As has been discussed above, every routing approach has its own advantages and disadvantages. Tables 2, 3, 4 summarizes the relevant works in reactive, proactive, geographic, and DTN network. From the literature study, both categorizes proactive and reactive has a balance in pros and cons, a low overhead result in power conservation achieved through requesting a path when needed (as in reactive). However, waiting for a route to be built (delay time) is not much suitable unless the network is too dense of nodes and in a slow mobility pattern. Ready on request routes as in proactive is required to minimize the end-to-end delay. Nevertheless, it draining limited battery power as well as keeping a view of network topology always up-to-date required high computational resources. Also, it suffers from high latency, high control traffic as compared to reactive protocols. Hence, geographical routing protocols benefit from physical location information of nodes to deliver packets ordering nodes in clusters, zones, or hieratical order. Geographic protocols seem to benefit from other categorized returns, acting as proactive in the zone and reactive outside zone. Exploiting location information and saving packets to expiration time makes it suitable to fit in some disaster scenarios.

In general, it has been observed that the research community put huge and fruitful efforts in AODV, as a representation of the reactive approach to improve its performance in various scenarios. However, the comparison results in Table1 revealed that a proactive approach with ready on request paths for use is more interested in disaster areas. Thus, the development of the geographic approach could be promising in the routing field.

6 Conclusion

In this paper, various protocols from different categories: reactive, proactive, DTN, and geographic have been presented, analyzed, and discussed to consider their suitability in disaster area communication. Each protocol has its pros and cons that are investigated accurately and summarized. DTN shows high delay and reliable message delivery meanwhile proactive presents high overhead and power draining. While Reactive protocols also suffer from high delay, waiting for a path to build. Geographical routing protocols seems to conserve limited network resource by neglecting routing tables but it floods the network with a message in greedy principle. It is critical to investigate these protocols on specific disaster scenarios to consider and evaluate their results. The suggested scenario may have to be analyzed with consideration of applications and conditions.

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