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Review of Mobile Ad Hoc Network Protocols

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Abstract: *Mobile Ad-hoc Network is one of the types of Wireless Ad-Hoc Networks which has distinguished characteristics. It is a self-configuring, decentralized and infrastructure less wireless network where mobile nodes in such a network communicate with each other through wireless links. Since the nodes can move around, routing in such a setup is always a challenge. To overcome this challenge of routing as a prerequisite to network communication, the Mobile Ad hoc Networking (MANET) routing protocols must establish an efficient route between network nodes. It should also be able to adjust efficiently to the frequently varying topology of moving nodes. In this paper, the main characteristics and the research challenge of routing in MANET, which may be considered in designing various routing protocols were discussed. Various MANET protocols surveyed and their classification; proactive, reactive and hybrid discussed. The review also present the strength and weaknesses of some specific protocols, discuss the various extensions made to the major protocols by researchers in this field and itemized out areas of future research work.*
Keywords: *Hybrid, MANET, Protocols, proactive, Reactive*

I. Introduction

The proliferation of mobile computing and communication devices such as cell phones, laptops, handheld digital devices, personal digital assistants and wearable computer devices is driving a revolutionary change in information society. We are moving from the Personal Computer age to the Ubiquitous Computing age in which a user utilizes, at the same time, several electronic platforms through which he can access all the required information whenever, wherever and however needed. The nature of ubiquitous devices makes wireless networks the easiest solution for their interconnection and, as a consequence, the wireless networking has been experiencing exponential growth in the past decade. Multi-hop, infrastructure-less nature of mobile ad hoc network without base station make it paramount for nodes to relay messages for several other nodes for data packets to reach the desired destination.

The architecture of a typical ad hoc network is shown in Figure 1. Differently from Wireless Local Area Networks (WLANs) and mesh networks, no infrastructure or centralization point is available to coordinate network functionality and radio resource allocation, so nodes in an ad hoc network must be able to self-organize, set-up, and maintain a suitable set of wireless links, as well as to implement all necessary networking protocols necessary for adequate functionality of the network. As one might have imagined, the development of protocols for such networks is challenging and is the subject of much ongoing research.

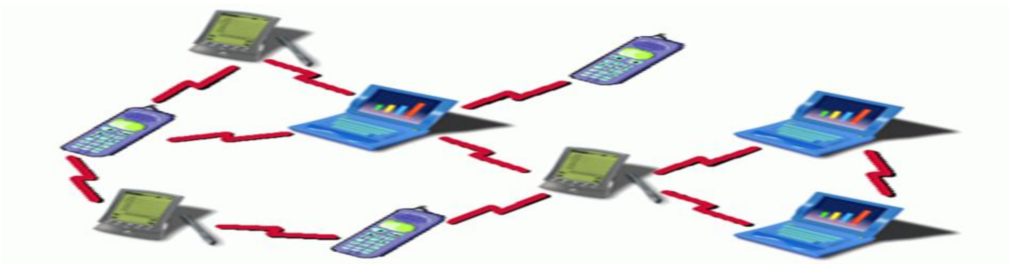

Figure 1: Mobile Ad hoc Network Source: http://www.ece.iupui.edu/~dskim/manet/

A) Evolution of MANET

The field of wireless and mobile communications has experienced an unpredictable growth in recent times. Presently, third-generation (3G) cellular systems have reached a high penetration rate, enabling worldwide mobile connectivity. Mobile users can use their cellular phone, iPads to check their email and browse the Internet. Recently, an increasing number of wireless local area network (LAN) hot spots are emerging, allowing travellers with portable computers to surf the Internet from airports, railways, hotels and send messages to other public locations. Broadband Internet access as lead to various wireless LAN solutions in the home, offices and such likes for sharing access between computers and other peripherals. In the meantime, 3G cellular networks are evolving to 4G, offering higher data rates, and personalized services.

As prerequisites to wireless network a fixed network infrastructure with centralized administration is required for their operation, potentially consuming a lot of time and money for set-up and maintenance. This challenge and the increasing number of devices such as laptops, personal digital assistants (PDAs), pocket PCs, tablet PCs, smart phones, MP3 players, digital cameras, that are provided with short-range wireless interfaces is driving a new alternative way for mobile communication, in which mobile devices form a self-creating, self-organizing and self-administering wireless network, called a mobile ad hoc network. In addition, these devices are getting smaller, cheaper, more user friendly and more powerful. This mobile ad hoc network, or MANET, does not rely on a fixed infrastructure for its operation as opposed to infrastructure wireless networks, where each user directly communicates with an access point or base station.

Bluetooth as an IEEE 802.15.1 network operates over a short range, at low power, and at low cost. It is essentially a low-power, short-range, low-rate cable replacement technology for interconnecting notebooks, peripheral devices, cellular phones, and smartphones, whereas 802.11 is a higher-power, medium-range, higher-rate access technology. For this reason, 802.15.1 networks are sometimes referred to as wireless personal area networks (WPANs). The link and physical layers of 802.15.1 are based on the earlier Bluetooth specification for personal area networks 802.15.1 networks operate in the 2.4 GHz unlicensed radio band in a Time-division multiplexing (TDM) manner, with time slots of 625 microseconds Whenever any Bluetooth-enabled devices come within range of each other, they instantly transfer address information and establish small networks between each other, without the user being involved. [1, 26]

In 1960, ARPANET demonstrated Packet switching technology which provided great swear for dynamically sharing bandwidth among multiple users. It offered a means to adaptively route traffic in response to dynamic changing network scenarios and user needs. In 1972, the US Department of Defense (DoD) started a research work to develop and demonstrate a Packet Radio NETwork (PRNET). Its scope was to render an efficient means of sharing a broadcast radio channel as well as to cope with the changing and incomplete connectivity [22].

In 1983, Defense Advanced Research Projects Agency (DARPA) started a project named SUrvivable RAdio Networks (SURAN). SURAN significantly improved upon the radios, scalability of algorithms and resilience to electronic attacks. The routing protocols in SURAN were based on hierarchical link-state and provided high scalability. This provided a packet switched network to the mobile battlefield in an environment without any wired infrastructure. This project proved to be useful in improving the radios' performance by making them smaller, cheaper and more pliant to electronic attacks. [13, 22]

In the late 1980s, many of the concepts of packet radio networking had been demonstrated in a variety of DoD programs. Concomitantly, packet radio technologies were being explored in the amateur and commercial sector. Amateur radio was used as the underlying connectivity to support packet communications and to create an amateur packet radio network [13, 22].

In the early 1990s, a number of new developments elicited a new era in ad hoc networking. Notebook computers became popular, as did open source software and viable communications equipment, based on Radio Frequency (RF) and infrared. DoD around the same time, continued funding programs such as the Global Mobile Information Systems (GloMo) and the Near Term Digital Radio (NTDR). These projects were initiated to support the defense requirements. The objective was to support Ethernet type multimedia connectivity anytime and anywhere between wireless devices. Channel access approaches were in the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

In the mid-1990s, due to the necessity for open standards in this emerging area of computer communication, a working group within the Internet Engineering Task Force (IETF), termed MANET working group, was formed to standardize the protocols and functional specifications of ad hoc wireless networks. The vision of the IETF effort for the MANET working group was to provide improved and standardized routing functionality to support self-organizing mobile networking infrastructure. The development of routing within the working group and the larger community resulted in the invention of reactive and proactive routing protocols [22]. Subsequently, the IEEE 802.11 subcommittee standardized a medium access protocol that was based on collision avoidance and tolerated hidden terminals, making it usable for constructing mobile ad hoc networks, prototypes out of notebooks and 802.11 cards. High Performance Radio Local Area Network (HIPERLAN) and Bluetooth were some other ad hoc network standards that addressed and benefited from ad hoc networking. Currently, mobile ad hoc network research is a very vibrant and active field for research works

B) Challenges of manet implementation

The major challenges faced by this architecture can be broadly classified as:

i. Dynamic topologies: Nodes are free to move arbitrarily; thus, the network topology which is typically multi hop, may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links.
ii. Device discovery- since nodes are free to join and move out of the ad hoc network at will, discovering relevant newly moved in nodes and information about their existence need dynamic update to facilitate automatic optimal route selection for packet transmission.
iii. Limited Bandwidth: channel considerations in ad hoc networks are poor compared to wired network. Congestion could be regular occurrences.
iv. Energy-constrained operation: Some or all of the nodes in a MANET may rely on batteries or other exhaustible means for their energy. For these ad hoc nodes, one of the most important system design criteria for optimization will be energy conservation.
v. Interoperability**:** an interoperable internetworking capability over a heterogeneous networking infrastructure will be necessary to be able to exploit full benefit of MANET [15].
vi. Limited physical security**:** Mobile wireless networks are generally more prone to physical security threats than are fixed-cable networks, MANET is not exempted from this challenge. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be considered. [2, 3]
vii. Scalability: The larger the size of ad hoc network the greater the complexity of managing the network and the communication links. Ad hoc networks are currently considered as an adequate architecture for networks composed of up to a few tens of nodes.

C) Real Life Application of MANET

i. Tactical Networks like Military communication and operations, automated battlefields,
ii. Emergency Services such as Search and rescue operations, Disaster recovery, Replacement of fixed infrastructure in case of environmental disasters, Policing and firefighting, Supporting doctors and nurses during out-of-base operational cases.
iii. Commercial and Civilian environments; E-commerce: electronic payments anytime and anywhere, Business: dynamic database access, mobile offices and Vehicular services: road or accident guidance, road and weather conditions, taxi cab network, inter-vehicle networks, Sports stadiums, trade fairs, shopping malls, Networks of visitors at airports.
iv. Home and enterprise: Conferences and Meeting rooms, Networks at construction sites
v. Education: Universities and campus settings, Virtual classrooms, Ad hoc communications during meetings or lectures.
vi. Coverage extension: Extending cellular network access and linking up with the Internet, intranets and extranet.

II. Manet Routing Protocols

A mobile ad hoc network (MANET) is a temporary, self-organizing network of wireless mobile nodes without the support of any existing infrastructure that may be readily available on the conventional networks. Since there is no fixed infrastructure available for MANET with nodes being mobile, routing becomes a very important issue. A communications protocol is a system of digital message formats and rules for exchanging those messages in or between computing systems. Routing protocols are usually engaged to determine the routes following a set of rules that enables two or more devices to communicate with each other. One of the major challenges in building a MANET is equipping each device to continuously maintain the information required to properly route traffic for other nodes in the network [16]. Due to the unpredictable location and possible mobility of mobile nodes, classical routing protocols used on wired networks are not suitable for Ad-hoc Wireless Networks. Some specific routing protocols were thus defined for ad-hoc networks taking into account their particularities. This is in contrast to older network technologies in which some designated nodes, usually with custom hardware such as routers, switches and hubs perform the task of forwarding the data. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations. Routing protocols are usually engaged to determine the routes following a set of rules that enables two or more devices to communicate with each other. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. MANET protocols are classified into three different categories: proactive, reactive and hybrid protocols.

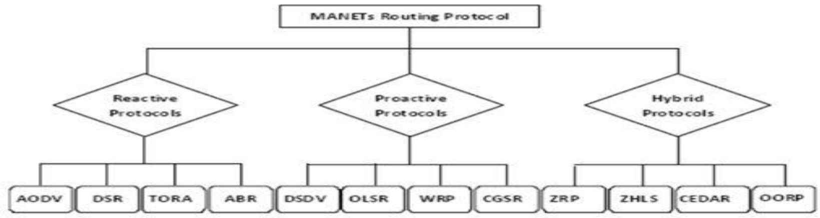

Figure 2: Ad hoc Network Routing Protocols Classification, [9]

2.1 Proactive Protocols

In a proactive routing, each node intermittently broadcasts its routing table to its neighbors, allowing all nodes to have a consistent network topology view. Proactive routing protocols maintain the routing information of all the participating nodes and update their routing information frequently irrespective of the routing requests. Proactive routing protocols transmit control messages to all the nodes and update their routing information even if there is no actual routing request. This makes proactive routing protocols bandwidth deficient, though the routing itself is simple having this prior updated routing information. The major drawback of proactive protocols is the heavy load created from the need to flood the network with control messages. Protocols such as Optimized Link State routing (OLSR), Destination Sequenced Distance Vector (DSDV), Fisheye State Routing (FSR) and Wireless Routing Protocol (WRP) are regarded as proactive routing protocol. [26]

A**. The Optimized Link State Routing Protocol (OLSR)**

OLSR is developed specially for mobile ad hoc networks. It is a table driven, proactive protocol; it exchanges topology information with other nodes of the network. Each node selects a set of its neighbor nodes as multipoint relays (MPR). In OLSR, only those nodes that were selected as MPR can forward control traffic to other nodes intended for routing. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required. Nodes which have been selected as multipoint relays by some neighbor node(s) announce link-state information for their MPR nodes periodically in their control messages. Thereby a node announces to the network that it has reachability to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. [15, 11]

The main disadvantages of Proactive Routing protocols including OLSR are:

i. Wastage of bandwidth due to unnecessary advertising of routing information.
ii. Maintaining a routing table for each node and advertising of this table leads to overhead, which consumes more bandwidth.
iii. Regular update of its routing tables uses up battery power.
iv. Slow reaction on restructuring and failures.
v. Many redundant route entries to the specific destination needlessly take place in the routing tables.

B. Destination-Sequence Distance Vector (DSDV)

Destination-Sequence Distance Vector (DSDV), (Perkins and Bhagwat 1994) as a proactive unicast mobile ad hoc network routing protocol was built on traditional Bellman–Ford Algorithm with improvement on routing mechanism to adapt to mobile ad hoc networks. The routing tables of DSDV contains; an address of the next hop toward a destination, the cost metric for the routing path to the destination, and a destination sequence number that is created by the destination. To distinguish stale paths from fresh ones, sequence numbers are used; sequence numbers also avoid route loops. As peculiar to proactive routing, every node periodically transmits updates including its routing information to its immediate neighbors. A routing table can be updated either in a full dump (the entire routing table is included inside the update) or an incremental update (which contains only those entries that, with a metric, have been changed since the last update was sent).

The DSDV protocol requires each mobile station to broadcast its own routing table to all current neighbors the advertisement must be made often enough to ensure that every mobile computer can almost always locate every other mobile computer of the collection. This leads to high reachability. In MANET, each mobile computer agrees to relay data packets to other computers upon request. This agreement places a demand on the ability of the routing mechanism to determine the shortest number of hops for a route to a destination; if the nodes are in sleep node, they are not disturbed. In this way a mobile computer may exchange data with any other mobile computer in the group, even if the target of the data is not within range for direct transmission. [21, 26]

The strength of DSDV includes the following:

i. DSDV is an efficient protocol for route discovery with high reachability
ii. Route discovery latency is lower.
iii. Loop-free paths are guaranteed in DSDV.

Weaknesses of DSDV include:

i. As common to proactive routing, to maintain network topology at each node, DSDV needs to send a lot of control messages.
ii. DSDV generates a high volume of traffic for high-density and highly mobile networks.
iii. Bandwidth is wasted in sending control messages.

2.2 **Reactive Protocols**

In contrast, a reactive routing protocol does not need to periodically broadcast the routing table hence improving network bandwidth at better than proactive protocols. A node forms a route to its destination, only on request. The consequence of this is that a node may be delayed for long, waiting for a long time before it can transmit the data packets this is because a node may not immediately know which neighbor to select as the next hop to forward the packet due to the dynamic network topology. As a result, the node has to find a new route dynamically to the destination node. Reactive protocols establish the route only when it is required unlike the proactive protocols these protocols do not update their routing information frequently and will not maintain the network topology information. Reactive protocols carry out the connection establishment process just before communication.

Reactive methods are based on demand for data transmission. Routes between hosts are determined only when they are explicitly needed to forward packets. Reactive methods are also called on-demand methods. They can significantly reduce routing overhead when the traffic is lightweight and the topology changes less dramatically, since they do not need to update route information periodically and do not need to find and maintain routes on which there is no traffic. [17, 14]

Reactive routing protocols begin a route discovery to a destination node when the source node has data packets to send to a destination. After discovering the route, the route maintenance is initiated to keep the route until it becomes no longer required, or the destination node is not reachable anymore. Thus, with reactive routing protocols two main phases are involved: Route Discovery phase and Route Maintenance phase [15]. Protocols such as Ad-hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Associativity-Based Routing (ABR) and Temporally Ordered Routing Algorithm (TORA) were example of reactive protocols [18].

A. Ad hoc On-Demand Distance Vector (AODV)

The Ad hoc On-Demand Distance Vector (AODV) routing protocol is particularly intended for use by mobile nodes in an ad hoc network. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. It uses destination sequence numbers to ensure loop freedom at all times. When a source node running AODV attempts to send a packet to a destination, but it does not have a valid route in its routing table, it will broadcast a Route Request (RREQ) to discover a route for the destination. The traveling RREQ will set up reverse paths pointing from the nodes receiving the RREQ back to the source node. Each node processing the RREQ records its neighbor’s address from which the first copy of the RREQ is received, as the next hop towards the source node. If the destination or a node knowing the destination receives the RREQ, it wills unicast a Route Reply (RREP) back to the source node through the path established by the RREQ. Each node forwarding the RREP will also create a route entry from itself to the destination. To maintain route entries, each node keeps track of its active connectivity to its next-hop nodes by the use of local Hello messages. If a node detects a broken link to one of its neighbors, it may either broadcast or unicast a Route Error (RERR) message to all the concerned nodes. [15]

Weakness of AODV

i. The usage of periodic hello message to track neighboring nodes causes network overhead in AODV.
ii. The initial search latency before transmission may degrade the performance of interactive applications.
iii. Quality of paths is not predetermined, and must be monitored by all intermediate nodes at the cost of additional latency, link failure and shorter network life time. That makes AODV quite unsuitable for real life applications.
iv. AODV cannot utilize routes with asymmetric links between nodes and thus require symmetric links.
v. Nodes in AODV store only route that are needed. Nodes use the routing caches to reply to route queries. These results in uncontrolled replies and repetitive updates in hosts caches which does not stop the propagation of all query messages which are flooded all over the network [19, 26].

B. Dynamic Source Routing (DSR).

As a routing protocol for wireless networks, it is similar to AODV in that it forms a route on-demand when a transmitting node makes a request. However, it uses source routing instead of relying on the routing table at each intermediate device. This protocol is based on source routing whereby all the routing information is maintained at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (the route record which is initially contained in Route Request would be inserted into the Route Reply). To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Request message header (this make it necessary that all links are symmetric). In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. The Route Discovery Phase is initiated to determine the most viable route. End-to –End delay of DSR is very high, this was due to DSR algorithm that uses cached routes, sending of traffic onto stale routes, causes retransmissions and leads to excessive delays [23, 9]

The main disadvantages of Reactive Routing protocols in general are:

i. High latency time is required in finding the route to the destination,
ii. Flooding too can lead to network clogging.
iii. RREP, RREQ & RERR messages leads to Control overhead. [6]

2.3 Hybrid Protocols

Hybrid routing protocols combine the features of both proactive and reactive routing protocols and these protocols are designed to improve network performance by allowing nodes with close proximity to work together to form a zone based network topology in order to reduce the route discovery overheads. This is mostly achieved by proactively maintaining routes among nearby nodes and reactively maintaining routes for far away node neighbors. Protocols such as Geographic Routing Protocol (GRP), Zone routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS), Distributed Spanning Tree Routing (DST), CEDAR (Core Extraction Distributed Ad Hoc Routing) and Distributed Dynamic Routing (DDR) could be classified as hybrid routing protocol. [12]

The main disadvantages of Hybrid Routing Protocols are:

i. Large overlapping of routes.
ii. Longer delay if route not found immediately,
iii. The nodes having to maintain high level topological information which leads to more memory and power consumption.
iv. Core nodes movement affects the performance of the protocol
v. In case of CEDAR the route establishment and computation is relied on core nodes.

A. Zone Routing Protocol (ZRP)

In wireless networking, ZRP is the first hybrid routing protocol with both proactive and reactive routing components. ZRP is proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by route discovery in reactive routing protocols. ZRP defines a zone around each node consisting of the node's k-neighbourhood (that is, all nodes within k hops of the node). A proactive routing protocol, Intra-zone Routing Protocol (IARP), is used inside routing zones, and a reactive routing protocol, Inter-zone Routing Protocol (IERP), is used between routing zones. A route to a destination within the local zone can be established from the source's proactively cached routing table by IARP. Therefore, if the source and destination of a packet are in the same zone, the packet can be delivered promptly. Most of the existing proactive routing algorithms can be used as the IARP for ZRP. For routes beyond the zone of a node, route discovery is reactively executed. The source node sends a route request to the border nodes of its own zone, containing its own address, the destination address and a unique sequence number. Border nodes are nodes which are exactly k hops away from the source. Each border node checks its local zone for the destination. If the destination is not a member of this local zone, the border node adds its own address to the route request packet and forwards the packet to its own border nodes. If the destination is a member of the local zone, it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to the destination.

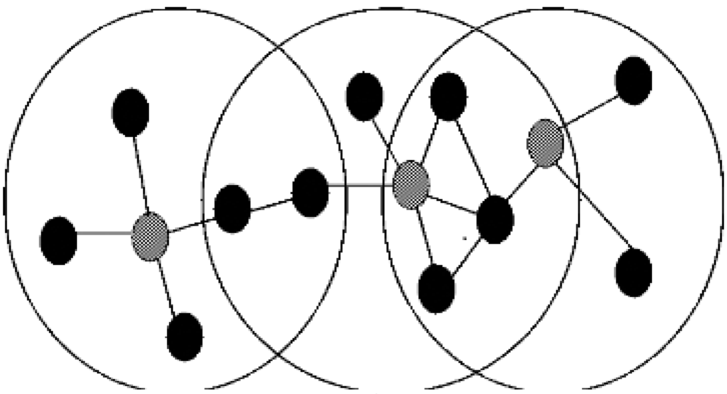

Figure 3. Display of node in Zones [10]

According to Mansuri et al (2011), ZRP tries to maintain (the most up-to-date map of the network and spend less time in sending messages and it requires less bandwidth.

Weakness of ZRP

i. Potential inefficiency may occur when RREQ cut across the entire network too often, this lead to flooding.
ii. To some extent this protocol can provide a better solution in terms of reducing communication overhead and delay. But this benefit is subjected to the size of a zone and the dynamics of a zone.
iii. ZRP does not provide an overall optimized shortest path if the destination has to be found through IERP. Moreover with the increase of network size ZRP could create unpredictable large overhead.
iv. In ZRP each path to a destination may be suboptimal. This also means that each node will have higher level topological information. Thus poses a higher memory requirement and an extra burden on the network resources.
v. Another major drawback is that a node that roams away from the reach of any zone cannot receive packets [19].

B. Core Extraction Distributed Ad Hoc Routing (CEDAR)

In proactive algorithms, routing information is exchanged periodically while in reactive algorithms, it is exchanged on demand. Most routing algorithms designed for ad-hoc networks assume that every node has the capability of being a router. This means that every node must maintain the state of the network and must exchange this information with every other node. Trying to avoid all this overhead, the Core Extraction Distributed Ad hoc Routing (CEDAR) algorithm proposes the election of a core network that is responsible for all the route computation. [26]

A set of nodes is dynamically elected to form the core of the network, so that each of them maintains the local topology of the nodes that belong to its domain. The core nodes propagate information about bandwidth availability on the stable links of the core network and keep information about dynamic and low-bandwidth links. By doing this, all route computations are restricted to the core nodes. Whenever a node needs to establish a connection to another one, it contacts the core node of its domain. This core node computes a core path to the destination domain and uses this core path as a directional guideline for the establishment of a short stable admissible QoS route from the source to the destination [13]. The major drawback to this algorithm that the battery power of core nodes runs out easily because of frequent computation and route maintenance.

3.1 Review Of Various Extended Protocols

A wide diversity of protocols have been proposed, only three protocols are accepted as experimental Request For Comments(RFC), namely Ad hoc On-Demand Distance Vector (AODV), Optimized Link State Routing (OLSR), and Topology Dissemination Based on Reverse-Path Forwarding (TBRPF). The Dynamic Source Routing Protocol (DSR) is expected to be accepted as a RFC in a near future. (http://www.ietf.org/html.charters/manet-charter.html). Many researchers have carry out evaluations on these protocols, pass their comments and suggest ways of improvement [9, 5]. The following are some of the extensions made to some of the protocols and more research work is still necessary since none has been accepted for large scale implementation.

A. Multirate Ad hoc On Demand Distance Vector (MR-AODV)

Guimaraes,, 2008 in the Ph. D thesis titled,' Quality of Service on Ad-hoc Wireless Networks' proposed a reservation based QoS mechanisms called BRAWN (Bandwidth Reservation over Ad-hoc Wireless Networks). This he based on the computation of the available bandwidth seen by a given node and the use of this value to verify whether new flows can still be routed through the node. The basic idea behind this approach is the estimation of the available bandwidth by each. This is done by forcing nodes to measure the transmission time of the packets and its activity periods. Using AODV, an additional field is added to the Route Requests packets (RREQ) to propagate the measurements when a new route is searched. This information is taken into account by the destination before sending the Route Reply (RREP) packet, so that several RREQs are received and a RREP is sent only over the less congested path. The simulation over extended AODV called MR-AODV (i.e. Multirate MR-AODV), prove that the proposal guarantees certain QoS levels and distributes the traffic more evenly among network nodes. However, the approach can lead to a high network delay for specific transmission when network is very busy and nodes bandwidth is almost exhausted. The issue of flooding through multiplication of route request was not considered by this approach.

B. Flooding Reduced-Destination Sequenced Distance Vector (FR-DSDV)

Karthikeyan (2010) in his Ph. D thesis titled ‘Reducing Broadcast overhead using optimum density based model for probability flooding in MANET’, evaluated the performance of three routing protocols namely Dynamic Source Routing (DSR), Ad hoc On demand Distance Vector (AODV), and Destination Sequenced Distance Vector (DSDV). The simulation results reveal the impact of broadcast mechanism in proactive routing protocol (DSDV) and reactive routing protocols (DSR and AODV) on network performance with respect to broadcast overhead, network load, MAC load, and throughput. It is proved that the DSDV and AODV are the protocols having high overhead due to the heavy use of broadcasting in their protocol design. This simulation results motivate the author to propose a Flooding Reduced-Destination Sequenced Distance Vector (FR-DSDV) which implemented Optimum Density based model for Probability Flooding instead of simple flooding implemented in traditional DSDV. In this method, each node will decide to forward or drop the received message based on transmitting node densities and as well as its previous neighbour nodes densities. The simulation results reveal that the new approach FR-DSDV improves the network performance by reducing the Medium Access Control (MAC) load, routing load, collision and power consumption when compared to traditional DSDV. He recommends the approach could be implemented for other protocols. This approach will not be the best in a scenario where the nodes mobility rate is high since the transmission is network density dependent. If the nodes move too often, the density changes too often and this will make the network unstable.

C. Multipath QoS Aware Reliable Reverse Routing Algorithm (MQARR-AODV)

Santhiya (2013), in his thesis titled “Multipath Efficient Ad-Hoc On Demand Distance Vector Routing Algorithms For MANET”, aims at developing three new efficient multipath routing algorithms based on the AODV routing algorithm with better QoS provisions. The research work proposes a novel Bee inspired Dynamic Multipath QoS Aware Reliable Reverse Routing algorithm (MQARR-AODV) based on AODV routing protocol with the incorporation of Artificial Bee Colony algorithm with modifications for effective routing. The proposed MQARR-AODV algorithm discovers routes on demand using a reverse route discovery procedure. The performance of the newly developed routing algorithms is analyzed and they are compared with the performance of the reactive protocol AODV. The developed algorithms MQARR-AODV, was simulated using NS2.33. The results received show that the MQARR-AODV improves Packet Delivery Ratio (PDR). However, the work does not consider security in multipath routing and multiple responses to every RREQ message from all available paths to the destination node which can constitute serious flooding as the network size increases. Only Random mobility model is considered, other mobility algorithm like group mobility algorithm is also common in human endeavors.

D. Optimized Ad hoc Demand Distance Vector (OAODV)

Suberthra et al (2013) in a paper titled energy efficient OAODV routing protocol in mobile ad hoc network, design and evaluate the performance of OAODV which is based on the remaining energy of intermediate nodes to maintain the connectivity of the network as soon as possible. The algorithm improved the Packet Delivery Ratio (PDR) and throughput when compared with traditional AODV but network delay was not given a priority.

E Secured Zone Routing Protocol (SZRP)

Abuhaiba and Abu –Thuraia (2012), propose the following four mechanisms in order to provide a comprehensive secure routing that can defend against major vulnerabilities in ad-hoc networks.

The first mechanism is the identity - based key management that does not depend on any trusted key distribution center Certification authority. This mechanism provides an identifier that has a strong cryptography binding with the public key of the node. The second mechanism is for a secure neighbor discovery, to ensure the correct view of neighbor information. It uses a combination of time and location to verify the discovery of legal nodes and prevent a malicious node from intruding into other node's radio transmission range, and thus preventing attacks such as wormhole, rushing, and replays attacks.

The third mechanism is relying on securing the control packets generated to perform route discovery, route maintenance, and routing tables' updates. Both digital signature and one - way hash function are used to achieve this. The fourth part is the detection of malicious nodes mechanism that identify misbehaving nodes and isolate them using blacklist. Simulations were carried out using NS2 simulator in several scenarios including mobility patterns. The security was achieved at the cost of additional latency and frequent mobility of nodes degrades network performance in most of the scenarios.

Table1. Performance Evaluation/Summary Of Manet Protocols

S/N	PROTOCOL	MAIN ACHIEVEMENT	WEAKNESS	REFERENCES
1	AODV - Adhoc On-demand Distance Vector	Adhoc On-demand Distance Vector-Route established on demand, use sequence number to find fresh route.	Stale route, Multiple Route reply, hello message increase overhead and latency during route searching	[6]
2	DSR - Dynamic Source Routing	Use no periodic routing advert, no bandwidth wastage when no traffic is taking place, avoid routing loop	Not scalable, stale routes, delay is very high, DSR will not be very effective in large networks or traffic intense networks as the volume of overhead carried in the packets will steadily increase as the network expands	[9,23]
3	DYMO	Energy efficient when network is large and mobility is high, applicable to memory constrained devices.	Performance degrades in low mobility scenarios, routing overhead is high for low traffic scenarios	[6]
4	OLSR - Optimized Link State Routing	Low latency due to periodic route maintenance, high throughput and minimal packet drop	Bandwidth wastage, high control overhead, regular updates consumes battery power, slow reaction on restructuring	[6, 9]
5	DSDV - Destination Sequence Distance Vector	It uses sequence number which will avoid the formation of loops	Low throughput, high routing overhead, DSDV requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle.	[14, 25]
6	ZRP – Zone routing Protocol	Benefit from proactive and reactive algorithm to avoid latency experience in reactive and reduce bandwidth wastage experience in proactive method.	Overlapping of routes, Demonstrated low packet delivery ratio when compared to DSR and AODV. Does not provide optimized shortest path. Design for LINUX environment	[6, 19, 20]
7	CEDAR- Core Extraction Distributed Ad hoc Routing	The main advantage of the CEDAR is that it makes use of core nodes to satisfy both routing establishment and QoS path computation. It is also very flexible in case of link breakage and restoring the connectivity of the network quickly and efficiently	Mobility of core nodes can degrade the network; route establishment and computation depend on core nodes. The battery of core nodes can easily run out and this will definitely obstruct the network.	[6, 13]
8	GRP – Geographic Routing Protocol	Maintain routing table, has reduce latency	Security challenges is high	[23]
9	MAODV – Multicast Ad hoc On-demand Distance Vector	Each node maintain both unicast and multicast routing tables	The major drawback of multicast is battery consumption and flooding, bandwidth wastage	[24]

10	SAODV – Security Awared AODV	Work on message tampering, message dropping and message replay	Message integrity and Neighbor authentication are not implemented.	[14]
11	MR-AODV Multirate Ad hoc On Demand Distance Vector	Guarantees certain QoS levels and distributes the traffic more evenly among network nodes.	However, the approach can lead to a high network delay for specific transmission when network is very busy and nodes bandwidth is almost exhausted	[13]
12	FR-DSDV - (Flooding Reduced-Destination Sequenced Distance Vector)	improves the network performance by reducing the Medium Access Control (MAC) load, routing load, collision and power consumption when compared to traditional DSDV	Network will be unstable where mobility is high since it is node density base	[21]
13	MQARR-AODV - Multipath QoS Aware Reliable Reverse Routing algorithm	Improves Packet Delivery Ratio (PDR).	However, the work does not consider security in Multipath routing and multiple responses to every RREQ message from all available paths to the destination node which can constitute serious flooding as the network size increases.	[22]
14	OAODV – Optimized Ad hoc Demand Distance Vector	Based on the remaining energy of intermediate nodes to maintain the connectivity of the network as soon as possible. The algorithm improved the Packet Delivery Ratio(PDR) and throughput when compared with AODV	Network delay as important as it is was left behind in the evaluation. Network life time will be very short since the connectivity depends on node energy	Suberthra et al (2013)

III. Conclusion

No particular algorithm or class of algorithm is the best for all situations but every protocol has its own strength and weaknesses as highlighted in table1. From the literature review so far, proactive protocols exhibits reduced latency, but poor bandwidth management. Reactive protocols demonstrate fair bandwidth management but higher latency in most cases. Hybrid tries to benefit from the advantages of both proactive and reactive algorithms to effectively manage the bandwidth and reduce network latency. This is done at the expense of some other parameters like packet delivery ratio and at times battery power. Other extensions were also reviewed, each of the research work attempt to solve one or two of the challenges but no one major protocol has succeeded in solving all the problem of routing in MANET and it may not be realistic to have all the challenges resolve in one single algorithm

IV. Recommendation For Future Works

As at the submission of this work, none of the protocol has been accepted for general implementation by MANET research group set up by Internet Engineering Task force, hence the research work is still on going and the following areas still need research focus..

a) Effective routing without unnecessary flooding that causes congestion
b) Better algorithm to take care of both unicasting and multicasting in MANET
c) Routing algorithm that is deployable in real time application scenarios
d) Routing that will take care of security issues like Message integrity and Neighbor authentication
e) Stale route in reactive protocols
f) Routing technics that will be operating System independent
g) Scalability and mobility management in MANET
h) Effective Power management and control overhead reduction.

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