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MOBILE AD-HOC NETWORKS: APPLICATIONS AND CHALLENGES

Ms. Surbhi Dhiman
Research Scholar,
Deptt. of Computer Science &Engg.,
NIILM University, Kaithal

Dr. Sheetal Chaudhary
Professor,
Deptt. of Computer Science &Engg.,
NIILM University, Kaithal

Abstract
A Mobile Ad-hoc Network (MANET)is a type of network in which mobile nodes form a self-creating, self-organizing and self-administering wireless network that communicates with each otherwithout any external centralized control or established infrastructure. The wireless links in this network are prone to errors and go down often due to mobility of nodes, interference and less infrastructure.The intrinsic flexibility, lack of infrastructure, ease of deployment, low cost andpotential applications make it an essential part of future pervasive computing environments.In recent years, several routing protocols have been proposed for mobile Ad-hoc networks and well-known among them are DSR, AODV, ZRP and TORA. This research paper provides an overview of these protocols with their characteristics, functionality, benefits,limitations and then makes their comparative analysis soas to analyze their performance.
Keywords: AODV, MANET, TORA, DSR, IARP

1. Introduction

A Mobile Ad-hoc Network (MANET) is a decentralized, infrastructure-less network where wireless nodes move randomly.Ad-hoc networks can be accessed anytime, anywhere, autonomous with cost effective and limited or no communication infrastructure. An Ad-hoc network represents complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary, ‘‘Ad-hoc’’ network topologies, allowing people and devices to seamlessly work in areas with no pre-existing communication infrastructure[GHO 2010]. Wireless also means that there is a shared environment, and some energyis consumed due to neighborhood transmissions. The nodes are exhausting their batteries not only by sending their own packets, but also by just listening to packets from other nodes.The Ad-hoc networks can be categorized according to their application such as Mobile Ad-hoc NETwork(MANET), Wireless Sensor Network (WSN), Vehicular Ad-hoc NETwork (VANET)and Wireless Mesh Networks (WMN) [RAM 2017].

The Mobile Ad-hoc Network (MANET) has become a key communication technology in various domains such as, military battlefield communications where soldiers need to decide for a defend or offend, rescue operational command centers, vehicular networks, law enforcement establishing where only law enforcing personnel need to communicate while others are not allowed to do so to prevent spreading of rumors, disaster recovery where the communication infrastructure is stopped.The wireless links in this network are highly error prone and can go down frequently due to mobility of nodes, interference and less infrastructure [KUS 2010]. Mobile Ad-hoc networks also open up new business opportunities for telecom operators and service providers. Appropriate business scenarios, applications and economical models need to be identified together with technological

advances, making a transition of Ad-hoc networks to the commercial world viable[HOE 2004]. A diagrammatic representation of mobile ad hoc network is shown in fig 1.

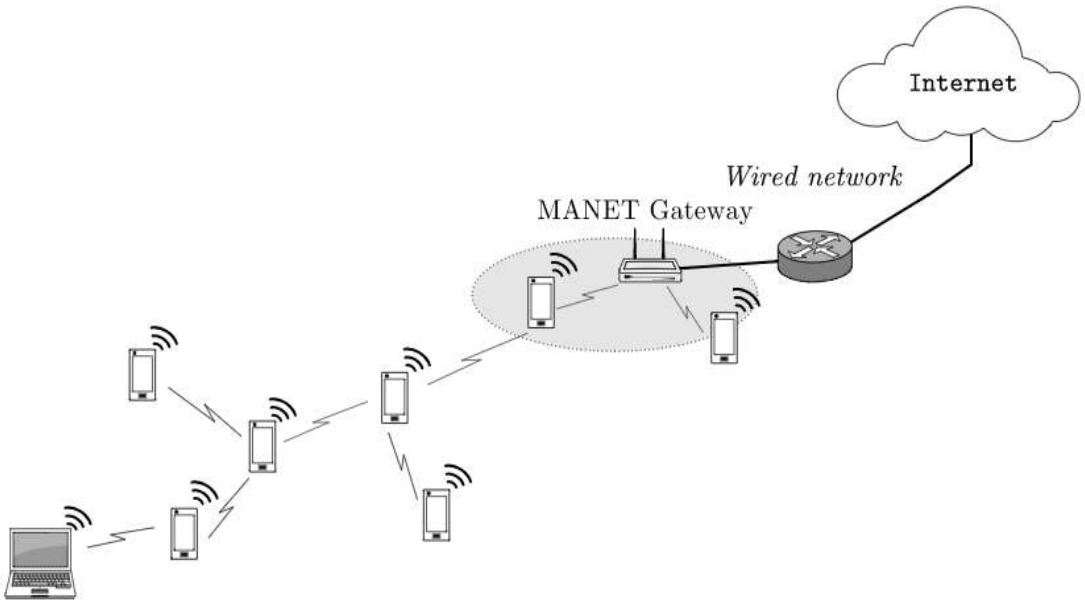


Fig. 1 Wireless Ad-hoc Network

2. Literature Survey

The problem of securityin Ad-hoc networks has received attention among researchers and many routing protocols devoted to Ad-hoc networks have been proposed.

Jeffery P. Hansen, Scott Hissam, Daniel Plakosh and Lutz Wragediscussed an approach for application-specific Quality of Service (QoS) expectations inAd-hoc wireless networks where the available bandwidth swings. The proposed algorithm, D-Q-RAM (Distributed QoS Resource Allocation Model) incorporates a distributed optimization heuristic that results in near optimal adaptation without knowing, estimate, or predict the available bandwidth at any moment of time[HAN 2012].

Pravin Ghosekar and Girish Katkar made an attempt to provide a comprehensive overview of this dynamic field of wireless networking. They explained the dynamic role of mobile Ad-hoc networks in the evolution of future wireless technologies and alsoreviewed activities in the area of MANETs, the characteristics, applications and capabilities[GHO 2010].

Ashwani Kush and Sunil Taneja described various routing protocols in mobile Ad-hoc networks. They provided an outline of the DSR, AODV and TORA protocols by presenting their characteristics, functionality, advantages and limitations [KUS 2010].

Jeroen Hoebeke, Ingrid Moerman, Bart Dhoedt and Piet Demeester described the potentialapplications of Ad-hoc networks and discussed the technological challenges that protocol designers and network developers face. These challenges include routing, service, Internet connectivity and resource discovery, billing and security[HOE 2004].

V. Park and M.S. Corson provided emphasis on a conceptual description of the Temporally Ordered Routing Algorithm (TORA) protocol which is a favorably adaptive distributed routing algorithm to operate in a mobile networking environment. The basic routing mechanism of TORA is neither a distance-vector nor a link-state algorithm; it is one of a kind of "link-reversal" algorithms [PAR 1997].

C. Perkins, E. B. Royer, S. Das presented an overview of protocol Ad-hoc on Demand Distance Vector (AODV) which is a variation of Destination-Sequenced Distance-Vector (DSDV) routing protocol which is collectively based on DSDV and DSR. It does not

maintain routes among every node in the network rather they are discovered as and when needed & are maintained only till they are required [PER 2003].

Singh, Woo and Raghvendrain, proposed a routing algorithm based on minimizing the amount of power required to send a packet from source to destination [SIN 1998].

Holland and Vaidya used DSR as a routing protocol to study the behaviour of TCP in Ad-hoc networks. The interaction between TCP and the Route Discovery and Route Maintenance mechanisms was enhanced in their work to allow TCP to correctly react to a route failure and not treating it as network congestion and to allow TCP to restart sending as soon as a new route to the destination is discovered[HOL 1999].

Stephen F. Bush proposed a metric which couples rate of change of network topology with the generic service to move itself to an optimal location with respect to changing network. This metric offered a fundamental tradeoff among adaptation to changing service location, performance and the network's ability to tune itself to a changing network topology[BUS 2005].

Swati Jaiswal, Satya Prakash, Neeraj Gupta and Devendra Rewadikarrepresentedissues in qualityof service in mobile Ad-hoc networks. Quality of service for a network is measured as guaranteed amount of data which a network transfers from one place to another in a given period of time. Quality of Service(QoS) support for Mobile Ad-hoc Networks is a challenging task due to their dynamic topology & limited resources. The main purpose of QoS routing is to find an achievable path which has sufficient resources to satisfy the constraints [JAI 2008].

Tauja Khurana, Sukhvir Singh and Nitin Goyal, studied the routing protocols based on their performance. They identified suitable routing protocols for use with WSN taking into view the limitations of the technology and proposed an enhanced protocol for WSN[KHU 2012].

Neerja Khatri and Arvind Kumar analyzed the performance of AODV protocol in MANET with various network parameters using a network simulator. They presented information related to AODV protocol and the modifications done to improve its performance[KHA 2012].

Nitin Goyal and Alka Gaba gave a general description of routing protocols, mainly Location Based Routing Protocols. They concluded that a protocol is still required to deal with energy efficient issues. A number of protocols are developed, still they have not considered energy efficient issues. There is still left a work in MANET to develop a protocol to have efficient storage capacity, computation capability, and power [GOY 2013].

SinaShahabi, MahdiehGhazvini and Mehdi Bakhtiariansuggested a new algorithm which improves the security of AODV routing protocol to come over the black hole attacks. This algorithm tries to recognize malicious nodes according to nodes behavior in an Ad-hoc network and further detach them from routing network. The proposed algorithm was simulated by NS2and showed improvements in end-to-end delay and packet delivery rate[SHA 2015].

Sandeep Kumar Arora, Shivani Vijan, Gurjot Singh Gaba implemented Intrusion Detection System (IDS) by amending the original AODV protocol and detaching the black hole node from the network that drops the maximum packets. They implemented the protocol by using NS-2 simulator. They also suggested a way of selecting the path of highest sequence number which is helpful in achieving the better Quality of Services (QoS). They analyzed the performance of the IDS technique over existing techniques which revealed the Packet Delivery Ratio is improved by 60% [KUM 2016].

HoudaMoudni, Mohamed Er rouidi, Hicham Mouncif, Benachir El Hadadianalyzed the impacts of black hole, flooding and rushing attacks which are threats in AODV routing

protocol using NS-2 network simulator. They looked for the network size, nodes mobility, traffic load and the number of the attackers in the network. The performance evaluation metrics used were packet delivery ratio, average end-to-end delay and throughput[MOU 2016].

3. Characteristics Of Mobile Ad-Hoc Networks

In MANET, each mobile node acts both as a host and router. That is, it is autonomous in behavior. The main characteristics which MANETs have to achieve are self-configuration, peer-to-peer connection among hosts and dynamic multi-hop routing. Some basic characteristics are:

- Multi-hop routing: When a source node and destination node is out of radio range, MANET finds out various paths through intermediate nodes which are in direct range of network, this is multi-hop routing process.
- Distributed Operation: There is no centralized firewall for overall security, routing and host configuration.There is infrastructure less topology.
- Topological dynamism: The topology of this network is dynamic in nature. The nodes can join or detach from the network anytime due to mobility and frequent node failure.
- Fluctuating Link Bandwidth: There is effect of high bit error rate common in wireless communication.
- Limited Energy Resources: Mobile nodes have less power, memory and weightless features. Wireless devices are battery operatedthus, designing mechanisms used to reduce energy consumption are: (a) devices go into sleep state when idle (b) routing paths that reduce energy consumption, (c) improve communication and data delivery structures to minimize energy consumption and (d) reduce overhead due to networking.

4. Applications of Mobile Ad-Hoc Networks

The Ad-hoc system is intended to be utilized where it is not dependably reachable. Its primary qualities are consistent connectivity with nodes in the network area and the way that the system comprises of taking an interested node. Several applications of Ad-hoc network are discussed below:

- Rescue operations: There are different circumstances when there is no infrastructure present, therefore it is important to build up a communication system. In situations like natural disaster, wars and emergency in immature nations, specially appointed systems i.e. ad hoc networks can convey rapidly and have no need of any framework.
- Home networks: Today, numerous family units have PCs in various rooms. People might want to connect these PCs to each other and transfer files so they do this by creating an ad hoc network between them.
- Educational Applications: Ad-hoc networks are used to setup virtual class & conference rooms.
- Games: This is an example of a completely commercial aspect of the Ad-hoc networks. People can play with the general population inside the network area. This is an awesome approach of interest in broad daylight zones as in trains, train stations or air terminals.
- MilitaryOperations: Mobile ad hoc networks are used in unmanned army system for surveillance and future combat operations. This has demanded the development of state-of-the-art MANET solutions for the reliability, security and scalability needs of the defense communications environment. It was the U.S Department of Defense that supported the principal exploration of specially employed systems to empower parcel

changing innovation to work without the confinement of an altered wired base [SHA 2017].

5. Challenges in Mobile Ad-Hoc Networks

There are several issues in Ad-hoc networks which make them very complex to integrate with the existing global network. The Mobile Ad-hoc NETwork(MANET) has become an important communication technology in the areas like military defense networks, rescue operations command centers, vehicular networks, etc.[TRI 2016]. Generally the most prominent problems are the identification of mobile terminals and the correct routing of mobile packets between each terminal.
The problems are discussed below:

- Routing: Routing is a most notable issue in wireless networks specially insystems having a consistent network of different nodes in its neighborhood. In this every node behaves as a switch and advances each other's data packages to enable data sharing between portable nodes.
- Security: A wireless link is much more vulnerable to attacks than a wired link. The user can insert spurious information into routing packets and cause routing loops, longtime-outstand advertisements of false or old routing table updates. Security has several unsolved issues that are needed to be solved to make the Ad-hoc networksagood solution.
- Quality of Service: QoS is a problematic job for the engineers, because of the fact that the topology of a specially appointed system will always show some signs of change in topology. Saving assets and maintaining a specific nature of administration, while the system condition continually changes, is exceptionally tedious [PER 2003].
- Load balancing: A load balancing strategy distributes MANET-Internet traffic between existing gateways, thus avoiding heavily loaded gateways where there are less loaded ones. The load balancing mechanism is applied at various points, e.g., during gateway discovery or gateway selection[MOJ 2020].
- Power Control: Power control is one of themain objective in specially appointed ad hoc system. Since each cell phone utilizes battery for force supply, yet it is for ashort-term period. Power consumption in cell phones count on upon various sort of directing conventions or steering strategies.

6. Survey Analysis on Routing Protocols

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

The AODV routing protocols are most suitable for those MANETs where there arefrequent instabilities in link connectivity due to topological alterations. Due to its inherentfeatures, dynamic link conditions in AODV get quickly adapted to by this protocol whichplaces it above other protocols in priority scale. Besides, it has other advantages also interms of processing and memory overhead and network utilization both of which are lowercompared to other protocols. Its ability to establish both unicast and multicast routesbetween sources and destinations is worth to point out here. Above all AODV's routingprotocols are loop-free.
Ad-hoc On Demand Distance Vector (AODV) is a reactive routing protocol which begins a route discovery process only when it has data packets to send out and there is no route path towards the destination node, that is, route discovery in AODV is called as on-demand[DHI 2017].
AODV is composed of two mainphases:

1. Route Discovery phase: It is initiated whenever a source node wants to communicate with another node, initially it has no routing information to do so. A flowchart depicting the basicroute discovery phase of a typical AODV protocol is shown in figure 2.
2. Route maintenance phase: This involves Route Error (RERR) and Route Repair (RREP) phases. Once a unicast route has been established between two nodes Source (S) and Destination (D), it is maintained as long as the source node S needs the route.
   AODV has a distinguishing feature of providing unicast, multicast and broadcast communication. AODV exercises a broadcast route discovery algorithm and then uses the unicast route reply message to maintain a path between source and destination node.

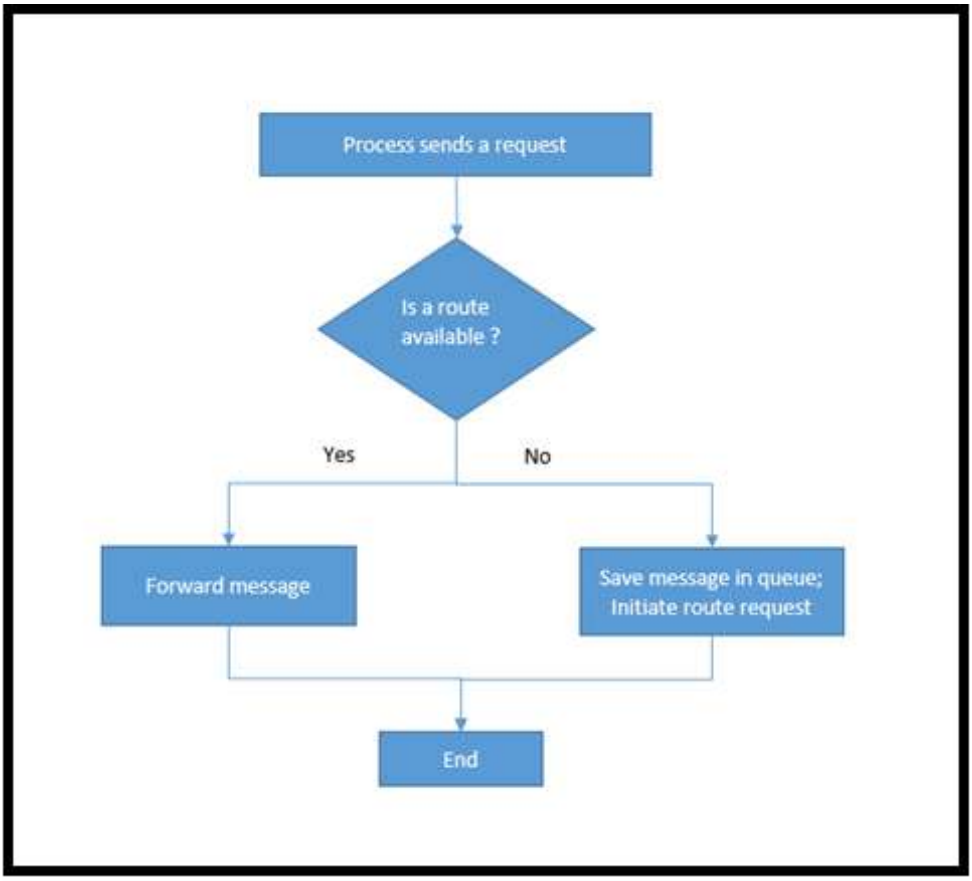


Fig 2. Flowchart for Route Discovery in AODV

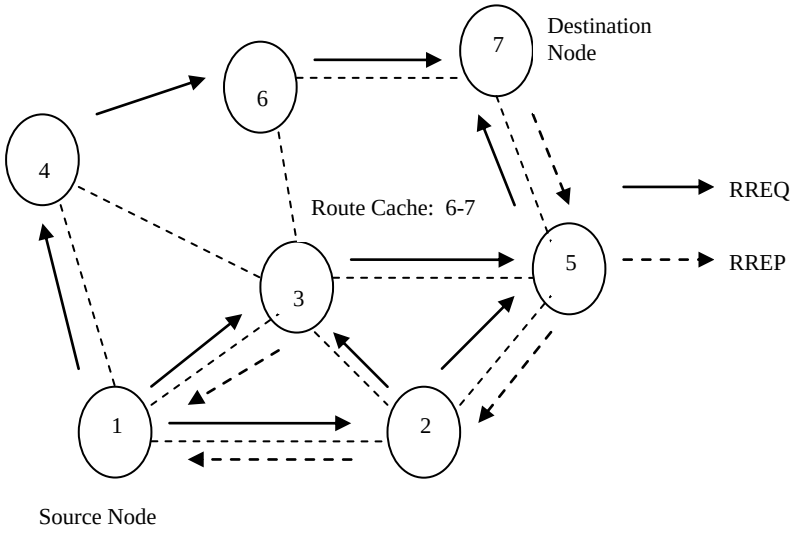


Fig 3. Route Discovery in AODV

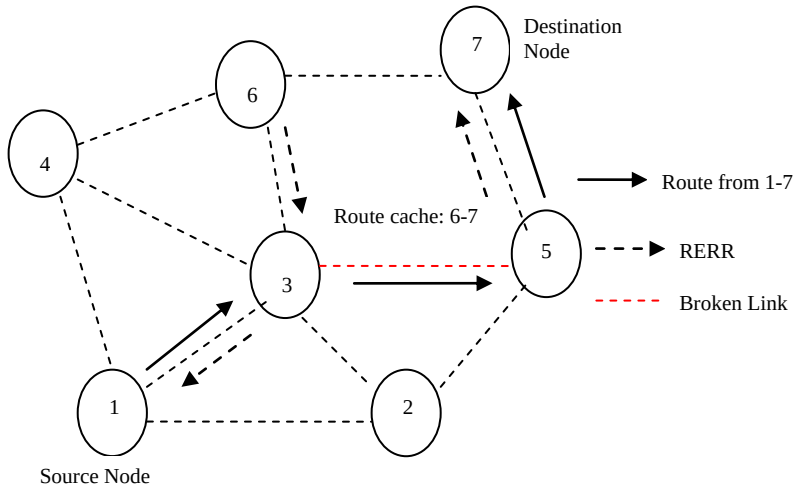


Fig 4. Route Maintenance in AODV

Advantages of AODV:

1. Adaptability to dynamic networks.
2. Reduced overhead.
3. Lower setup delay

Disadvantages of AODV:

1. Periodic updates
2. Inconsistent routes

II. Dynamic Source RoutingProtocol (DSR)

Dynamic source routing (DSR) is a standard prototype of routing protocols that depends on the minimum hop count parameter to provide the path between sender and receiver without taking into consideration any other factors like energy consumption and node energy level thatconsiderably affect the routing algorithm performance [SAL 2020].

Route finding cycle in DSR is on demand. It keeps maintenance of active routes. There is no periodic activity of any kind like hello messages as in AODV. This protocol exploits source routing, that is, entire route is part of the header.It uses caches to store routes. The

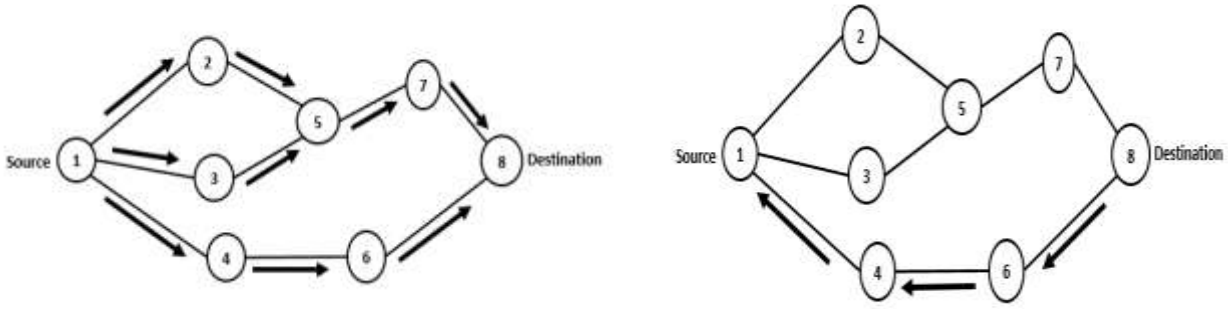
DSR protocol allows nodes to dynamically find a source route across multiple network hops to any destination in the Ad-hoc network. Each sent data packet carries in its header the complete, ordered list of nodes through which the packet must pass, allowing packet routing to be trivially loop-free and no up-to-date routing information in the intermediate nodes.There are two mechanisms in this protocol: Route Discovery and Route Maintenance, in which both work mutually to allow nodes to determine and maintain source routes to random destinations in the Ad-hoc network. Everyphaseof the protocol function entirely on-demand, permitting the routing packet overhead of DSR to automatically scale to changes in the routes currently in use.All routing is automatically determined and maintained by the DSR routing protocol when nodes in the network move or join or leave the network, and as wireless transmission conditions such as sources of interference change. Route creation process is shown in figure 5.

Advantages:

1. A route is established only when it is essential
2. No need to keep routing table.
3. Reducing load.

Disadvantages:

1. Route overheads.
2. Higher delay.
3. The route maintenance.
4. Not scalable to large networks.
5. Requires considerably more processing resources as compared to other protocols.



A. Propagation of Route Request (RREQ) Packet

B. Path taken by Route Reply (RREP) Packet

Fig 5. Routing in DSR Protocol

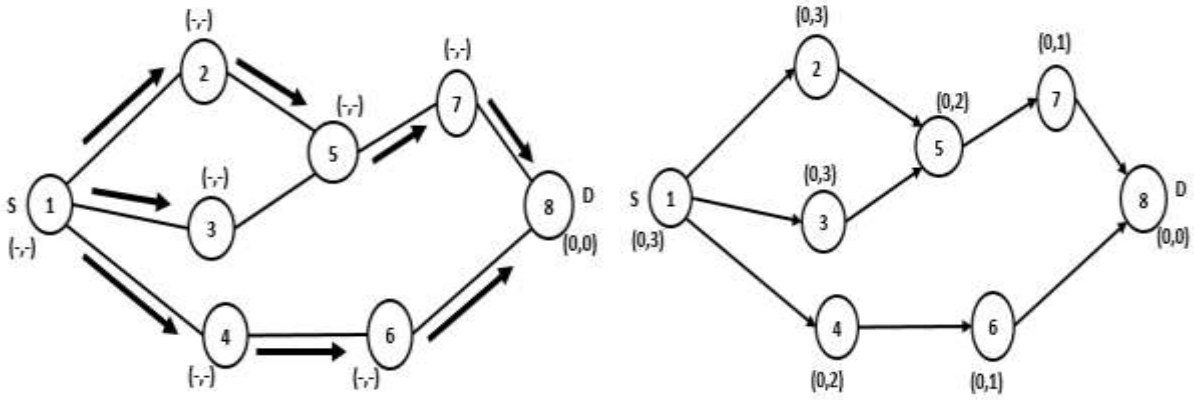
III. Temporally Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) is an on-demand routing protocol which is a highly adaptive, efficient and scalable distributed algorithm based on link reversal concept.TORA uses an arbitrary height parameter to determine the direction of link between any two nodes for a given destination.The main objective of TORA is to limit control message propagation in the highly dynamic, multi-hop mobile computing environment. It is a source-initiated on-demand routing protocol. It has anexceptional feature to maintain multiple routes to the destination so as to not require any reaction to topological changes. The protocol reacts only when all the routes to the destination node are lost. The protocol has three tasks: Route creation, Route maintenance and Route erasure as described below:

Route creation: When a node requires a route to a destination, it initiates route creation where query packets are flooded out to search for possible routes to the destination as shown in figure 6.

Route maintenance: The availability of multiple paths is a result of how TORA models the entire network as a directed acyclic graph (DAG) rooted at the destination. Route maintenance occurs when a node loses its all links to outgoing nodes. The node propagates an update packet which reverses the links to all of its neighboring nodes. TORA attempts to build the DAG which is rooted at the destination. The route maintenance task of TORA is the main drawback as this function produces a large amount of routing overhead. It causes the network to be overcrowded thus preventing data packets from reaching their destinations.

Route erasure:In the event that a node is in a network partition without a route to the destination, route erasure is initiated. Route erasure is operated by flooding clear packets throughout the network. When a node receives a clear packet, it updates the links to its neighbors as unassigned. After that, these clear packets propagate through the network and erase all routes to that unapproachable destination.



A. Propagation of route query by UPD (Reference level, height)

B. Height of each node updated

Fig 6. Route Creation in TORA

Advantages:

1. Multiple paths created.
2. Communication overhead and bandwidth utilization is minimized.

Disadvantages:

1. Routing overheads.
2. Depends on synchronized clocks among nodes.

IV. Zone Routing Protocol (ZRP)

The Zone Routing Protocol (ZRP) is a hybrid protocol which unites the features of both reactive and proactive routing protocols. The ZRP protocol comprises of threemain sections: (i) Intra Zone Routing Protocol (IARP) (ii) The Inter zone Routing Protocol (IERP), and (iii) Border cast Resolution Protocol (BRP).

IARP is a checked proactive routing protocol that furthers the performance of existing reactive routing protocols. It counts on the service of a neighbor discovery protocol (NDP) to deliver neighbor information.IARP may use a system based on the time-to-live (TTL) field in IP packets for controlling the zone range. The IERP reactively originates a route discovery process when the source node and the destination node are existing in different zones.IERP is the reactive routing component of ZRP. It is responsible for finding a global path. The route discovery in IERP is almost similar to DSR.When global queries are needed, the zone based broadcast service is used to proficiently guide route queries to other

nodes, rather than recklessly relaying queries from neighbor to neighbor. ZRP combines the benefits of both the reactive and proactive routing protocols.

Advantages:

1. Reduces the control overhead
2. Eliminates the delay for routing

Disadvantage:

1. Lack of route optimization

7. Conclusion

Mobile Ad-hoc networks are used in military operations, emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, or earthquake. In this paper we tried to inspect the introduction, characteristics and various challenges relating to mobile Ad-hoc networks and also analysed various routing protocols of MANETS with their advantages and disadvantages. While choosing a protocol for a specified network one should consider issues like size of the network i.e. the chosen protocol should support scaling issues, degree of mobility as how often bare links assume to cut off, user applicationsetc. The existing characteristics have made it necessary to find some effective security solutions and protect the MANETs from all kind of security risks.

Table 1 Comparison of various routing protocols

Protocol Property	AODV	DSR	TORA	ZRP
Loop Free	Yes	Yes	Yes	Yes
Multiple Routes	No	Yes	Yes	No
Category	Reactive	Both	Reactive	Proactive
Security	No	No	No	No
QoS Support	No	No	No	No
Power Efficiency	No	No	No	No

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