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# PERFORMANCE EVALUATION OF ON DEMAND PROTOCOLS FOR MANET

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**Abstract:** Mobile Ad Hoc Network (MANET) is collection of multi-hop wireless mobile nodes that communicate with each other without centralized control or established infrastructure. The wireless links in this network are highly error prone and can go down frequently due to mobility of nodes, interference and less infrastructure. Therefore, routing in MANET is a critical task due to highly dynamic environment. In recent years, several routing protocols have been proposed for mobile ad hoc networks and prominent among them are DSR, AODV and TORA. This research paper provides an overview of these protocols by presenting their characteristics, functionality, benefits and limitations and then makes their comparative analysis so to analyze their performance. The objective is to make observations about how the performance of these protocols can be improved.

## 1. INTRODUCTION

A wireless network enables to communicate and access applications and information without wires. This provides freedom of movement and the ability to extend applications to different parts of a building, city, or nearly anywhere in the world. Wireless networks allow people to interact with e-mail or browse the Internet from a location that they prefer. Wireless devices include personal digital assistants (PDAs), laptops, personal computers (PCs), servers, and printers. Computer devices have processors, memory, and a means of interfacing with a particular type of network [1]. The transmission system is usually implemented and administrated via radio waves where the implementation takes place at physical level [2].
There are three types of wireless networks as; a) Wide area networks (b) Wireless local area networks and (c) Personal area networks.

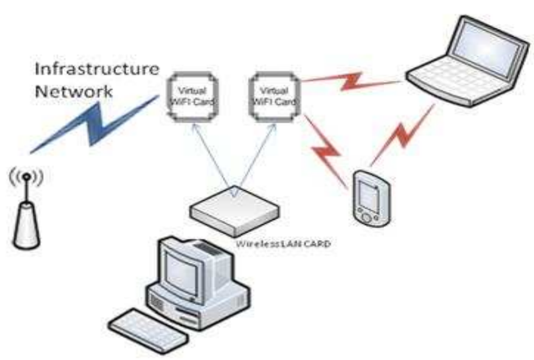
***(a) Wide Area Networks* [3]*:*** Wide Area Networks include the networks provided by the cell phone .Originally providing cellular voice services, the carriers added data services as well, at first by overlaying digital data services on top of the early analogue voice services, and later by building out brand new generation voice-plus-data networks. The carriers determine where to provide coverage based on their business strategy, and they also control Quality of Service (QoS). Some Wireless technical terms are: GSM/GPRS [ 3] - the voice plus data network technology offered by Rogers Wireless, updated to EDGE [ 3 ] in 2004. 1XRTT (usually called 1X) [ 3 ] - the latest voice plus data network technology offered by Bell Mobility and Telus Mobility. Both of these networks are completely incompatible with one another.

***(b) Wireless Local Area Networks*[3]*:*** Wireless LANs are networks are set up to provide wireless connectivity within a finite coverage area for e.g. university, the airport, or a gas plant. Wireless LANs work in an unregulated part of the spectrum, so anyone can create their own wireless LAN, in their home or office. Wireless LANs terminology is: 802.11 - this is the network technology used in wireless LANs. Wi-Fi – is a common name for the early 802.11b standard.

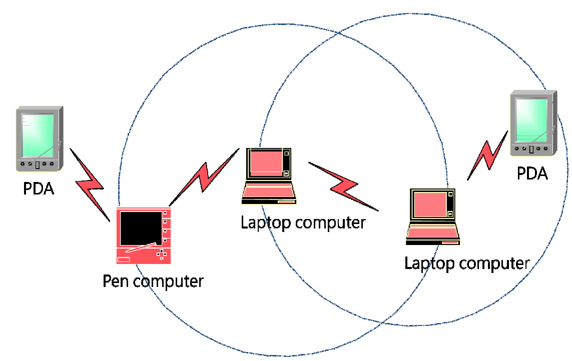
***(c)Personal Area Networks*[3]*:*** These are networks that provide wireless connectivity over distances of up to 10m or so. This range allows a computer to be connected wirelessly to a nearby printer, or a cell phone's hands-free headset to be connected wirelessly to the cell phone. This technology is called Bluetooth. [3]

**2.0 Mobile adhoc Networks (MANET) [4] [13]:**

MANET is an autonomous system and also collection of various cooperative mobile terminals. Such networks are multihop, self organizing and self configuring network. In present scenario, there are currently two variations of mobile wireless networks [4]. The first kind is known as the infrastructure networks or Base Stations. These networks communicate with the nearest base station which lies within the range. Typical applications of this type of network include office Wireless Local Area Networks (WLANs) [5]. The second type of wireless network is called as infrastructure less mobile network, commonly known as an Ad hoc Network. Due to no stationary infrastructure, all nodes can move freely, topology may change rapidly and unpredictably over time, and nodes have to form their own mutual infrastructures [4].




(i) Infrastructure Network




(ii) Infrastructure less Network

As the nodes in a MANET are mobile, the network topology may change rapidly and unpredictably. The network is decentralized which means that all network activity including route discovery, topology discovery, delivering messages and route maintenance must be executed by the nodes themselves, i.e. the nodes should be capable of performing the routing functionalities [6]. There is a cooperative engagement of a collection of mobile nodes without the required intervention of any centralized access point or existing infrastructure. Due to infrastructure less and self organizing nature of ad-hoc networks, it has several applications in the area of commercial sector for emergency rescue operations and disaster relief efforts [7].

***Characteristics of MANET include* [8] [15]*:***

I. Dynamic topologies: Nodes are free to move arbitrarily, thus the network topology change randomly and rapidly at unpredictable times.
II. Bandwidth-constrained links: Caused by the limits of the air interface. Furthermore, multiple access, multipath fading , noise and signal interference decrease the limited capacity available at the allocated frequency rate.
III. Energy-constrained operation: MANETs inherently imply an underlying reliance on portable, finite power sources.
IV. Limited security: Mobile networks are in general more vulnerable to eavesdropping, spoofing and denial-of-service attacks than fixed-cable network [8].

### *2.1 Design Issues of Mobile adhoc Networks* [8]*:*

A well designed architecture for mobile adhoc networks involves all networking layers ranging from physical layer to MAC layer. Information distribution such as node distribution, link failures, must be shared among layers, the MAC (medium access control) layer and the network layer need to collaborate in order to have a better view of the network topology & to optimize the number of messages in the network.

The main aspects of designing the physical transmission system are dependent on several characteristics of the radio propagation channel such as path loss, interference and fading. These aspects are taken into account while designing the modulation, coding, and power control features in the radio equipment. In principle, the radio equipment in the nodes forming a mobile ad hoc network can use any technology as long as it provides reliable links between neighboring mobile terminals on a common channel.

The MAC (medium access control) layer plays the key role in determining the channel usage efficiency by resolving contention amongst a number of unsupervised terminals sharing the common channel. An efficient MAC protocol allows coordinated access to the limited resources. The main goal of a MAC protocol is therefore maximizing the probability of successful transmissions and maintaining fairness amongst all users [8].

## 3.0 Literature Survey on MANET routing protocols:

Mobile ad hoc network does not rely upon any fixed support infrastructure. By varying distance, connectivity and disconnectivity of nodes can be controlled. So, routing is very important issue in adhoc networks. Each node in the network must be able to take care of routing of the data and can discover multihop paths [4].

Based on the method of delivery of data packets from the source to destination, classification of MANET routing protocols could be done as follows:

***(i) Unicast Routing Protocols:*** The routing protocols that consider sending information packets to a single destination from a single source.

***(ii)Multicast Routing Protocols:*** Multicast is the delivery of information to a group of destinations simultaneously, using the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the destinations split. Multicast routing protocols for MANET use both multicast and unicast for data transmission.

Some of the challenges [13] in MANET include:

1) Unicast routing
2) Multicast routing
3) Dynamic network topology
4) Speed
5) Frequency of updates or Network overhead
6) Scalability
7) Mobile agent based routing
8) Quality of Service
9) Energy efficient/Power aware routing
10) Secure routing [13].

Many routing protocols are proposed for MANET. The protocols are mainly classified in to three: categories as Proactive, Reactive and Hybrid [4] [9].

***Proactive routing*[4][15]*:***

It is also known as table driven approach [4]. In this type of routing, each node maintains the global topology of the network of the network and whenever node wants to send message to a particular destination, it checks its own routing table and uses the information for forwarding the data packet. The global topology is maintained by periodic update of routing information. Example of proactive routing protocols[ 10] are: Destination sequenced distance vector routing (DSDV), Wireless routing protocol (WRP), Cluster Gateway switch routing protocol(CGSR) [9], Global state routing(GSR) [9], Fish state routing(FSR)[9].

***(i).Destination sequenced distance vector routing protocols(DSDV)*[4] [15]** ***:*** The protocol Destination-Sequenced Distance-Vector routing (DSDV) is a Proactive routing protocol that solves the major problem associated with distance vector routing of wired networks i.e., Count-to-infinity, by using destination sequence number [9]. DSDV is an enhancement of Bellman Ford algorithm [7] [15]. In this mechanism, routes to all destinations are readily available at every node at all times. The tables are exchanged between neighbors at regular intervals to keep up-to-date view of the network [4]. To maintain consistency in routing table, DSDV sends routing updates periodically. Therefore, a lot of control message traffic which results in an inefficient utilization of network resources. To overcome this problem, DSDV uses two types of route update packets: *full dump, incremental packets* [7].

***(ii). Wireless Routing protocol (WRP)*[12]*:*** This routing protocol defined as the set of distributed shortest path algorithms that calculate the paths using information regarding the length and second-to-last hop of the shortest path to each destination.

For the purpose of routing, each node maintains four things:

I. A distance table
II. A routing table
III. A link-cost table
IV. A message retransmission list (MRL) [9].

WRP requires each node to maintain four routing tables. This introduces a significant amount of memory overhead at each node as the size of the network increases. Another disadvantage of WRP is that it ensures connectivity through the use of hello messages. These hello messages are exchanged between neighboring nodes whenever there is no recent packet transmission. This will also consume a significant amount of bandwidth and power as each node is required to stay active at all times (i.e. they cannot enter sleep mode to conserve their power) [11].

***(iii) Cluster Gateway switch routing protocol (CGSR)*****[4] [9]*****:*** The Cluster-head gateway switch routing protocol (CGSR) is a clustered multi-hop mobile wireless network with several heuristic routing schemes. In CGSR a cluster head controls a group of mobile nodes. A framework for code separation and channel access through which routing and bandwidth allocation is achieved. A cluster head selection algorithm is utilized to select a node as the cluster head using a distributed algorithm within the cluster. Using LCC cluster-heads only change when two cluster heads come into contact or when a node moves out of contact of all other cluster-heads. The main problem is transmission power limited by the number of cluster head changes in mobile ad-hoc network [12]. This protocol is designed to provide effective membership and traffic management. It is based on distance vector routing protocol. maintenance of cluster structure is a very difficult in CGSR [4].

***(iv) Global state routing (GSR)*****[9] [15]*****:*** It improves link state routing by avoiding flooding of routing messages. Each node maintains a Neighbors list, a topology table, a next hop table and a distance table [12]. It is based on the traditional Link State algorithm. In GSR, each node maintains a link state table based on the up-to-date information received from neighboring nodes, and periodically exchanges its link state information with neighboring nodes only. This has significantly reduced the number of control message transmitted through the network, but the size of update messages is relatively large, and as the size of the network grows they will get even larger. Therefore, a considerable amount of bandwidth is consumed by these update messages [11].

***(v). Fish state routing (FSR)*** **[4][9]*****:*** Fisheye State Routing (FSR) is an improvement of GSR [12].This protocol reduces the amount of traffic for transmitting the update messages. The basic idea is that each update message does not contain information about all nodes; it only contains update information about the nearer nodes more frequently than that of the farther nodes. Hence, each node can have accurate and exact information about its own neighboring nodes [9]. It alleviates problem of message overhead but it increases bandwidth issue when node density increases [4]. FSR is more scalable to larger networks [11].

FSR was designed to reduce message overhead in dynamic environment. Link state routing information broadcast the updated information throughout the network where as in FSR, routing information is disseminated. In this, node rapidly shares information with its nearest neighborhoods and less frequently with distant nodes. Thus it alleviates problem of message overhead but it increases bandwidth issue when node density increases [4]. FSR is that it uses a special structure of the network called the ‘‘fisheye” [9].

***Reactive routing* [15]*:***

Such protocols are superior to proactive routing protocols and are reactive in nature. These protocols are based on on-demand route discoveries therefore also known as on demand routing protocols. Thus route are determined when they are required by the source node [4] [15]. In this section three most popular reactive protocols dynamic source routing (DSR), Ad Hoc on demand distance vector(AODV) and Temporary Ordered Routing Protocol (TORA) [14] routing have been explained [10]:

***(i) Dynamic source Routing (DSR)* [7]*:***

DSR is a pure reactive routing protocol [15] which is based on the concept of source routing. DSR protocol is composed of two important phases: *route discovery* and *route maintenance* [7].

*Route discovery:* When a source node S (initiator) sends a packet to destination node (target node) D, it searches a possible route in its route cache. In this process, It stores discovered routes in route cache. Route discovery requires 7 fields during this process such as sourceid, destid, ReqID, Address list, Hop limit, Network Interface List, Acknowledgment list. Initially source node contains address list as empty and RREQ message contains 3 fields as source ID, destination ID,
Unique RREQ ID. Then source node broadcasts the message with in transmission range [4].

*Route maintenance:* To maintain this process, it is essential to maintain the routes that are stored in the route cache. Due to dynamic nature of the environment, any
route can fail anytime. Therefore, the route maintenance process will constantly monitors the network and notify the other nodes with the help of route error packets as well as route cache would be updated.

***(ii) Adhoc on demand distance vector routing protocols (AODV)* [7]*:***

AODV algorithm is pure reactive in nature and it contains the properties of both DSR and DSDV protocols. AODV algorithm is an improvement on DSDV in the sense that it minimizes the number of broadcasts [7] [15]. AODV is a variation of Destination-Sequenced Distance-Vector (DSDV) routing protocol which is collectively based on DSDV and DSR. It aims to minimize the requirement of system-wide broadcasts to its extreme. It does not maintain routes from every node to every other node in the network rather they are discovered as and when needed & are maintained only as long as they are required [13] [15].

It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address [11]. When a node wants to send a message to destination node, first it will check whether it has a valid route to the destination or not. If not, then it broadcast a *route request packet* (RREQ) to its neighbors which then forwards the request to their neighbors and so-on, until either it reaches to the intermediate node which has a valid route for the destination or the destination node. AODV uses destination sequence numbers to ensure that it contains most recent information and all routes are loop free. Once the route request has reached the destination or an intermediate node with a valid route, the destination/intermediate node responds by unicasting a *route reply (RREP) message* back to the neighbor node from which it first received the RREQ. The route maintenance process in AODV is performed with the *route error (RERR) message* [7].

**(iii) TORA (Temporary Ordered Routing Protocol) [14][12]:**

TORA is a distributed highly adaptive routing [15] protocol designed to operate in a dynamic multihop [4] network. TORA uses an arbitrary height parameter to determine the direction of link between any two nodes for a given destination. Consequently, multiple routes often exist for a given destination but none of them are necessarily the shortest route [15]. To initiate a route, the node broadcasts a QUERY packet to its neighbors. This QUERY is rebroadcasted through the network until it reaches the destination or an intermediate node that has a route to the destination. The recipient of the QUERY packet then broadcasts the UPDATE packet which lists its height with respect to the destination. When this packet propagates in the network, each node that receives the UPDATE packet sets its height to a value greater than the height of the neighbor from which the UPDATE was received. This has the effect of creating a series of directed links from the original sender of the QUERY packet to the node that initially generated the UPDATE packet [14]. When it was discovered by a node that the route to a destination is no longer valid, it will adjust its height so that it will be a local maximum with respect to its neighbors and then transmits an UPDATE packet. If the node has no neighbors of finite height with respect to the destination, then the node will attempt to discover a new route as described above. When a node detects a network partition, it will generate a CLEAR packet that results in reset of routing over the ad hoc network [15].

**4.0 Performance Metrics [15]:**

There are number of qualitative and quantitative metrics that can be used to compare reactive routing protocols. Most of the existing routing protocols ensure the qualitative metrics.

1. **Routing overhead:** This metric describes how many routing packets for route discovery and route maintenance need to be sent so as to propagate the data packets.
2. **Average Delay:** This metric represents average end-to-end delay and indicates how long it took for a packet to travel from the source to the application layer of the destination. It is measured in seconds.
3. **Throughput:** This metric represents the total number of bits forwarded to higher layers per second. It is measured in bps. It can also be defined as the total amount of data a receiver actually receives from sender divided by the time taken by the receiver to obtain the last packet.
4. **Media Access Delay:** The time a node takes to access media for starting the packet transmission is called as media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.
5. **Packet Delivery Ratio:** The ratio between the amount of incoming data packets and actually received data packets.
6. **Path optimality:** This metric can be defined as the difference between the path actually taken and the best possible path for a packet to reach its destination.

**5.0 Conclusion**

In this research paper, an effort has been made to concentrate on the comparative study and performance analysis of various on demand/reactive routing protocols (DSR, AODV and TORA) on the basis of above mentioned performance metrics. The results after analysis have been reflected in Table 1 and Table 2. The first table is description of parameters selected with respect to low mobility and lower traffic. It has been observed that the performance of all protocols studied was almost stable in sparse medium with low traffic. TORA performs much better in packet delivery owing to selection of better routes using acyclic graph. Table 2 is evaluation of same parameters with increasing speed and providing more nodes. The results indicate that AODV keeps on improving with denser mediums and at faster speeds. All efforts have been done to make the study biasless and using same metrics. Next work will concentrate on using some simulator and actually carrying out results using the given metrics.

**Table 1: Metrics w.r.t Low mobility**

| **High Mobility and High Traffic** | | | | |
|---|---|---|---|---|
| **Protocol** | **Routing overhead** | **Average end to end delay** | **Packet delivery ratio** | **Path optimality** |
| **DSR** | Average | Average | Average | Low |
| **AODV** | Very High | Average | Average | Average |
| **TORA** | High | More | Low | Average |

**Table 2: Metrics w.r.t High mobility**

| **Low Mobility and Low Traffic** | | | | |
|---|---|---|---|---|
| **Protocol** | **Routing overhead** | **Average end to end delay** | **Packet delivery ratio** | **Path optimality** |
| **DSR** | Low | Average | High | Average |
| **AODV** | Low | Average | High | Average |

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| | | | | |
|---|---|---|---|---|
| **TORA** | Moderate | Low | High | Good |

Table 3 is description of other important parameters that make a protocol robust and steady in most cases. The evaluation predicts that in spite of slightly more overhead in some cases DSR and AODV outperforms TORA in all cases. AODV is still better in Route updation and maintenance process.

It has been further concluded that due to the dynamically changing topology and infrastructure less, decentralized characteristics, security and power awareness is hard to achieve in mobile ad hoc networks. Hence, security and power awareness mechanisms should be built-in features for all sorts of applications based on ad hoc network.

**Table 3: Evaluation w.r.t other parameters**

| **Protocol** | **Category** | **Protocol Type** | **Loop Freedom** | **Multiple routes** | **Multicast** | **Security** | **Message Overhead** | **Periodic broadcast** | **Requires sequence data** | **Expiry of routing information** | **Summary** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **DSR** | On Demand or React | Source Routing | Yes | Yes | No | No | High | No | No | No | Route Discovery, Snoop |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ive | | | | | | | | | | ing |
| **AODV** | On Demand or Reactive | Distance Vector | Yes | No | Yes | No | High | Possible | Yes | Yes | Route Discovery, Expanding Ring Search, Setting forward path |
| **TORA** | On Demand or Reactive | Link Reversal | No | No | No | No | Moderate | Possible | Yes | No | Route UPDATE packets |

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