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Performance Evaluation of MANET Routing Protocols

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Abstract

The task of finding and sustaining routes in Mobile Ad-hoc Networks (MANETS) is an important factor in determining the efficiency of any MANET protocol. MANET characteristically is an autonomous system of mobile nodes connected by wireless links without any centralised infrastructure. Absence of fixed infrastructures and host mobility thus network may experience rapid and unpredictable topology changes. Hence, routing is required in order to perform communication among the entire network. There are several routing protocols namely proactive, reactive and hybrid etc. In this paper we will discuss the active research work on these routing protocols and its performance evaluation. To this end, we adopt a simulation approach, which is more suitable to this kind of analysis

***Index* words- MANET, Proactive and Reactive and Hybrid routing protocols, Unicasting, Multicasting**

1. INTRODUCTION:

In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users. Mobile Ad Hoc Networks (MANETs) provide communication between all nodes in the network topology without the presence of a centralized authority; instead all nodes can function as routers. This gives the MANETs two of its most desirable characteristics; adaptable and quick to deploy. In particular, a very large no. of recent studies focused on Mobile Ad-Hoc Networks (MANETs) [1] [2]. This kind of self organizing network is very useful when the fixed infrastructure is economically practical or physically possible such as battlefield Scenarios, natural disaster, and etc.

Many routing protocols are proposed for MANET. The protocols are mainly classified in to three categories: Proactive, Reactive and Hybrid. Proactive routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. Reactive routing protocols create routes only when desired by the source node. Once a route has been established, it is maintained by a route maintenance procedure. Hybrid routing protocols are proposed to combine the merits of both proactive and reactive routing protocols and overcome their shortcomings.

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

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

This paper aims to achieve a short description of three main classes of protocol namely proactive, reactive and hybrid is presented. Then, these routing protocols are compared in terms of performance metrics. The purpose of referring to performance metrics in this paper is to compare proactive and reactive and hybrid protocols according to these metrics. Many publications have compared the performance of the routing protocols using the packet delivery ratio, control overhead, hop count, and end-to-end delay. However, the performance of routing protocols in this paper is mostly evaluated in terms of: Loop freedom, control overhead, memory overhead, and scalability of the routing algorithms.

2. ROUTING PROTOCOL PERFORMANCE ISSUES:

QoS consists of a set of characteristics or constraints between the source and the destination that a connection must guarantee during the communication in order to meet the requirements of an application [1] [2]. To judge the merit of a routing protocol, one needs metrics both qualitative and quantitative, with which to measure its suitability and performance [3]. Generally, there are four main metrics presented in [4] as parameters of QoS which are probability of packet loss (or packet delivery ratio), delay (route latency), jitter (delay variance), and bandwidth. Table 1 provides a list of popular qualitative and quantitative properties of MANET routing protocols based on RFC2501 [3]. Some of the metrics in [3] are applied to compare the proactive and reactive and hybrid routing protocols in terms of overhead, scalability, and loop-freedom.

Table.1MANET ROUTING PROTOCOLS PERFORMANCE METRICS :

Quantitative metrics	Qualitative metrics
End-to-End Delay	Loop-freedom
Throughput	Route stability
Overhead	On-demand or proactive
Packet Delivery Ratio	Scalability
Mobility	Reliability

4. PROACTIVE ROUTING PROTOCOLS:

These protocols are also called as Table-Driven protocols since they maintain the routing information even before requiring of this information [10]. Each and every node maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically updated as the network topology changes.

4.1 Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

The protocol Destination-Sequenced Distance-Vector routing (DSDV) [6] 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. In this routing protocol, each mobile node in the network keeps a routing table. Each of the routing table contains the list of all available destinations and the number of hops to each. Each table entry is tagged with a sequence number, which is originated by the destination node. Periodic transmissions of updates of the Routing tables help maintaining the topology information of the network. If there is any new significant change for the routing information, the updates are transmitted immediately. So, the routing information updates might either be periodic or event driven. The routing updates could be sent in two ways: one is called a ‘‘full dump’’ and another is ‘‘incremental.’’ In case of full dump, the entire routing table is sent to the neighbors, where as in case of incremental update, only the entries that require changes are sent.

4.2. Wireless Routing Protocol (WRP)

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. WRP reduces the number of cases in which a temporary routing loop can occur. For the purpose of routing, each node maintains four things: 1. A distance table 2. A routing table 3. A link-cost table 4. A message retransmission list (MRL). WRP uses periodic update message transmissions to the neighbors of a node. Each time the consistency of the routing information is checked by each node in this protocol, which helps to eliminate routing loops and always tries to find out the best solution for routing in the network.

4.3. Cluster Gateway Switch Routing Protocol (CGSR)

This protocol modifies DSDV by using a hierarchical cluster-head-to-gateway routing approach to route traffic from source to destination. Gateway nodes are nodes that are within the communication ranges of two or more cluster heads. A packet sent by a node is first sent to its cluster head, and then the packet is sent from the cluster head to a gateway to another cluster head, and so on until the cluster head of the destination node is reached. The packet is then transmitted to the destination from its own cluster head. By forming several clusters, this protocol achieves a distributed processing mechanism in the network. However, one drawback of this protocol is that, frequent change or selection of cluster heads might be resource hungry and it might affect the routing performance.

4.4. Global State Routing (GSR)

In GSR protocol [6], nodes exchange vectors of link states among their neighbors during routing information exchange. Based on the link state vectors, nodes maintain a global knowledge of the network topology an optimize their routing decisions locally. Functionally, this protocol is similar to DSDV, but it improves DSDV in the sense that it avoids flooding of routing messages.

4.5. Fisheye State Routing (FSR)

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. Instead, it 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. The novelty of FSR is that it uses a special structure of the network called the ''fisheye.''

4.6. Hierarchical State Routing (HSR)

HSR [7] combines dynamic, distributed multilevel hierarchical clustering technique with an efficient location management scheme. This protocol partitions the network into several clusters where each elected cluster head at the lower level in the hierarchy becomes member of the next higher level. The basic idea of HSR is that each cluster head summarizes its own cluster information and passes it to the neighboring cluster heads using gateways. After running the algorithm at any level, any node can flood the obtained information to its lower level nodes. The hierarchical structure used in this protocol is efficient enough to deliver data successfully to any part of the network.

4.7 Source Tree Adaptive Routing (STAR)

The Source Tree Adaptive Routing (STAR) protocol [8] has significantly decreased the routing overhead disseminated in the network by employing a least overhead routing approach (LORA) to exchange routing information. It also employees optimum routing approaches (ORA) if required. This protocol scales very well for large networks since it has significantly reduced the bandwidth consumption for routing updates.

4.8. Distance Routing Effect Algorithm for Mobility (DREAM)

DREAM is a multi-path, location-aware routing protocol. In DREAM, each node knows its geographical coordinates through a Global Positioning System (GPS). The coordinates are periodically exchanged between each node and stored in a routing table. The advantage of exchanging location information compared to link state or distance vector information where complete information are exchanged is less bandwidth consumption resulting in good scalability of this protocol.

5. REACTIVE ROUTING PROTOCOLS:

Another approach used for routing is reactive approach [6,7].This type of routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network.

5.1 Ad-Hoc On-Demand Distance Vector (AODV) Routing Protocol:

AODV [9] is a single-path, reactive routing protocol. Route discovery is using a route request (RREQ) – route reply (RREP) cycle. When a source node has data to be sent to a destination node and does not know the route to the destination node, floods a route request (RREQ) packet throughout the network. Several RREQ packets, each travelling on a different path, will reach the destination. The destination node replies (RREP packet) only to the first RREQ packet and drops subsequent RREQ packets with the same source sequence number and broadcast ID. The RREQ packet that arrived at the earliest is likely to have traversed a path with low delay and/or hop count. Representing the weight of each link in the network by the delay incurred on the link, AODV reduces to finding a minimum-weight path between the source and the destination.

5.2Dynamic Source Routing (DSR) protocol

This protocol requires each transmitted packet to carry the full address from the source to the destination likewise the mechanism used in AODV. It [10] uses shortest hop path from the source to the destination. Thus, the source learns multiple route to the destination and stores them in the route cache. It does not check for node disjoint or link disjoint properties before using these routes. DSR fits into the category of routing protocols based on minimum weight path routing.

5.3 Temporally Ordered Routing Algorithm (TORA)

TORA [11] is a scalable, highly adaptive distributed routing algorithm designed to operate in a highly dynamic mobile networking environment. TORA is based on the concept of “link reversal”. The protocol is particularly designed to localize algorithmic reactions to topology changes by maintaining multiple routes to the destination. Shortest hop paths are given secondary importance and longer routes are often used to reduce the overhead of discovering newer routes. Thus, TORA fits under the stability category. In addition, TORA supports multicasting but it should be used in conjunction with lightweight adaptive multicast algorithm (LAM) to support multicasting. The disadvantage of this protocol is producing temporary invalid routes similar to the LMR.

5.4 Associativity-Based Routing (ABR)

The ABR [12] protocol uses a query-reply technique to determine the routes to the destinations. However, in ABR route selection is primarily based on stability. In order to select stable route each node maintains an associativity tick with its neighbors and the links with higher associativity tick are selected in preference to the ones with lower associativity tick. The disadvantage of ABR is that it does not maintain multiple routes or a route cache so the alternate routes will not be immediately available.

5.5Cluster-Based Routing Protocol (CBRP)

This is a hierarchical protocol, and this protocol is grouped into the clusters. Each cluster has its cluster-head which coordinates the data transmission within the cluster and the other clusters. The advantage of CBRP is that only cluster heads exchange the information, therefore the number of the control packets transmitted through the network is less than traditional flooding methods significantly. The disadvantage of this hierarchical method is the large number of overhead associated with cluster formation and maintenance and it has also temporary routing loops.

6. HYBRID ROUTING PROTOCOLS:

Hybrid routing protocols are proposed to combine the merits of both proactive and reactive routing protocols and overcome their shortcomings.

6.1 Zone Routing Protocol (ZRP)

Zone routing protocol is a hybrid routing protocol which effectively combines the best features of proactive and reactive routing protocol [13,14]. Each node defines a zone around itself and the zone radius is the number of hops to the perimeter of the zone. The reactive global search is done efficiently by querying only a selected set of nodes in the network [15]. The number of nodes queried is in the order of [r zone / r network]2 of the number of nodes queried using a network-wide flooding process [13].Unless the zone radius is carefully chosen, a node can be in multiple zones and zones overlap.

6.2 Zone-Based Hierarchical Link State Routing Protocol(ZHLS)

In ZHLS protocol [10], the network is divided into non overlapping zones as in cellular networks. Each node knows the node connectivity within its own zone and the zone connectivity information of the entire network. The link state routing is performed by employing two levels: node level and global zone level. The zone level topological information is distributed to all nodes. Since only zone ID and node ID of a destination are needed for routing, the route from a source to a destination is adaptable to changing topology. The zone ID of the destination is found by sending one location request to every zone.

7. OTHER ROUTING PROTOCOLS:-

There are some other routing protocols that do not rely on any traditional routing mechanisms, instead rely on the location awareness of the participating nodes in the network. Recently, some of the researchers proposed some location-aware protocols that are based on these sorts of idea. Some of the examples of them are Geographic Distance Routing (GEDIR)[17], Location-Aided

Routing (LAR)[18], Greedy Perimeter Stateless Routing (GPSR)[19], Geo-GRID[20], Geographical Routing Algorithm (GRA)[21], etc. Other than these, there are a number of multicast routing protocols for MANET. Some of the mentionable multicast routing protocols are: Location-Based Multicast Protocol (LBM)[22], Multicast Core Extraction Distributed Ad hoc Routing (MCEDAR)[23], Ad hoc Multicast Routing protocol utilizing Increasing id-numberS (AMRIS)[24], Associativity- Based Ad hoc Multicast (ABAM)[25], Multicast Ad hoc On-Demand Distance-Vector (MAODV) routing [26],Differential Destination Multicast (DDM)[27],On-Demand Multicast Routing Protocol (ODMRP)[28], Adaptive Demand-driven Multicast Routing (ADMR) protocol [29], Ad hoc Multicast Routing protocol (AMRoute)[30], Dynamic Core-based Multicast routing Protocol (DCMP)[31], Preferred Link-Based Multicast protocol (PLBM)[32],etc. Some of these multicast protocols use location information and some are based on other routing protocols or developed just as the extension of another unicast routing protocol. For example, MAODV is the multicast-supporting version of AODV.

Table 2: Comparison of Proactive Routing Protocol

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Parameter	*DSDV*	*WRP*	*CGSR*	*GSR*	*FSR*	*STAR*	*OLSR*	*DREAM*
Routing Philosophy	Flat	Flat	Hierarchical	Flat	Flat	Hierarchi cal	Flat	Flat
Multicast Capability	No	No	No	*No*	*No*	*No*	*No*	*No*
Number of Required Tables	Two	Four	Two	Three and a list	Three and a list	One and Five Lists	*Three*	*One*
Frequency of Update Transmission	Periodically & as Needed	Periodical ly & as Needed	Periodically	Periodic , local	Periodic, local	Conditio nal	Periodic	Mobility Based
Advantage	Loop free	Loop free	Loop free	Localize d updates	Reduce CO	Employs LORA and ORA	Reduced CO and connecti on	Low CO and MO
Disadvantage	High overhead	High MO	High overhead	High MO	High MO, Reduced Accuracy	High MO, processin g overhead	2-hop neighbo r knowled ge required	Require s GPS

CO: control overhead; MO: Memory Overhead: LORA: least overhead routing approach; ORA: optimum routing approach

8.Review results of proactive routing protocols:

Proactive routing protocols tend to provide lower latency than that of the on-demand protocols, because they try to maintain routes to all the nodes in the network all the time. But the drawback for such protocols is the excessive routing overhead transmitted, which is periodic in nature without much consideration for the network mobility or load.

Table 3: Comparison of Reactive Routing Protocol

Parameter	AODV	DSR	TORA	ABR	CBRP
Routing Metric	Freshest & Shortest Path	Shortest Path	Shortest Path	Shortest Path & Strongest Associatively	First available route
Route Maintained in	Route Table	Route Cache	Route table	Route table	Only cluster-heads exchange routing information

Route Reconfiguration Methodology	Erase Route; Notify Short	Erase Route; Notify Short	Link reversal & Route Repair	Localized Broadcast Query	Erase Route; Notify Short
Loop Free	Yes	Yes	Yes	Yes	Temporary routing loops,
Multiple Route	No	Yes	Yes	No	No
Advantage	Adaptive to highly, Dynamic topologies, Low overhead	Multiple routes, Loop Free Promiscuous overhead	Multiple routes	Route stability	Only cluster-heads exchange routing information
Disadvantage	Scalability problems, Large delays, Hello messages	Scalability problems, Large delays	Temporary routing loops, Overall complexity	Scalability problems, High overhead, Overall complexity	Cluster maintenance, Temporary loops

9.Review results of Reactive routing protocols:

reactive protocols discover routes only when they are needed, they may still generate a huge amount of traffic when the network changes frequently. Depending on the amount of network traffic and number of flows, the routing protocols could be chosen. When there is congestion in the network due to heavy traffic, in general case, a reactive protocol is preferable. Sometimes the size of the network might be a major considerable point.

Table 4: Comparison of Hybrid Routing Protocol

Parameter	ZRP	ZHLS
Loop Free	yes	yes
Routing Philosophy	Flat	Hierarchical

10. Review results of Hybrid routing protocols:

Hybrid Routing Protocols is to use proactive routing mechanism in some areas of the network at certain times and reactive routing for the rest of the network. The proactive operations are restricted to a small domain in order to reduce the control overheads and delays. The reactive routing protocols are used for locating nodes outside this domain, as this is more bandwidth efficient in a constantly changing network.

Table 5. Shows compare the main characteristics of routing protocols

Routing class	**Proactive**	**Reactive**
Availability of route	Always available	Determined when needed
Control Traffic volume	Usually high	Lower than proactive routing protocols
Storage Requirements	High	Depends on the number of routes kept or required. Usually lower than proactive protocols
Delay level	Small since routes are predetermined	Higher than proactive
Scalability problem	Usually up to 100 nodes.	Source routing protocols up to few hundred nodes. Point-to-point may scale higher
Handling effects of mobility	Occur at fixed intervals. DREAM alters periodic updates based on mobility	Usually updates ABR introduced LBQ(Local Broadcast Query)AODV uses local route discovery
Security Support	No	No
Quality of service support	Mainly shortest path as the QoS metric	Few can support QoS , Although most support shortest path

Table 6:*COMPARISION OF PROACTIVE AND REACTIVE AND HYBRID ROUTING PROTOCOLS IN MANET:*

Routing class	**PROACTIVE**	**REACTIVE**	**HYBRID(ZRP)**
Routing structure	Both Flat and hierarchical structures	Mostly Flat, Except CBRP	Flat
Periodic updates	Yes, some may use conditional.	Not required. Some nodes may require periodic beacons.	Yes(Locally)
Control Overhead	High	Low	Medium

Route acquisition delay	Low	High	Lower for Intra-zone; Higher for Inter-zone
Bandwidth requirement	High	Low	Medium
Power requirement	High	Low	Medium

11. A COMPARISION OF REACTIVE AND PROACTIVE AND HYBRID ROUTING PROTOCOLS IN MANETS:

In this paper a classification of several routing schemes according to their routing strategy is provided A comparison of these two categories of routing protocols is presented, highlighting their features, differences, and characteristics in Table 4. By looking at performance metrics in Table 4 such as control traffic, control overhead, route acquisition delay, delay level, and characteristics of presented categories, a number of conclusions can be made from each category.

- In proactive routing flat addressing can be simple to implement, however this method may not scale good for large networks
- By using a device such as GPS: Like in DREAM protocol where the nodes in the network just exchange their location information rather than complete links-state or distance-vector information.
- By using conditional updates rather than periodic: For example in STAR updates occur based on conditions.
- FSR have reduced the routing overhead by localizing the update message propagation.
- AODV which are flooding based have scalability problem. The Route discovery and route maintenance which are two main mechanisms of reactive routing protocols can be controlled in order to improve the scalability.
- The CBRP protocol attempts to minimize the control overhead in route discovery phase by introducing a hierarchical on-demand routing protocol.
- ABR routing protocol a localized broadcast query (LBQ) is initialized when a link goes down.
- ZRP protocol attemps in order to reduce the control overheads and delays.

12. Quality of Service:

In the MANET, the network patterns change at any time, each node may change at any time position, that is, each node is the relationship with the adjacent node may change at any time, therefore, means that the need to provide QoS dependent on regular Beaconing, so that each node to master the situation around in order to provide effective QoS information. Beaconing make the overhead on the network increased, when the node mobility to improve even when the general information that may affect the transmission, which will be in the Ad Hoc Network to provide QoS, the biggest problem. It would be valuable to evaluate the well-known routing

protocols that have been suggested for MANETs based on the quantitative metrics presented in Table 1.

CONCLUSIONS:

In this paper we presented an exhaustive survey about existing routing protocols, and we comparison between the different papers, most of its conclusions pointed to a phenomenon, not a routing protocol can adapt to all environments, whether it is Table-Driven, On-Demand or a mixture of two kinds, are limited by the network characteristics; highlighting their features, differences. While it is not clear that any particular algorithm or class of algorithm is the best for all scenarios, each protocol has definite advantages and disadvantages and is well suited for certain situations. Often it is more appropriate to apply a hybrid protocol rather than a strictly proactive or reactive protocol as hybrid protocols often possess the advantages of both types of protocols.
More and more efficient routing protocols for MANET might come in front in the coming future, which might take security and QoS (Quality of Service) as the major concerns. So far, the routing protocols mainly focused on the methods of routing, but in future a secured but QoS-aware routing protocol could be worked on. There are still many issues and challenges which have not been considered. This will be subjected to further investigations.

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