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A reasonable learning of MANET routing protocols

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Abstract
Wireless mobile ad-hoc networks are characterized as networks without any physical connections. In these networks there are no fixed topology due to the Mobility of nodes, interference, multipath propagation and path loss. Hence a dynamic routing protocol is needed for these networks to function properly. Many routing protocols have been developed for accomplishing this task. The Main purpose of such an ad hoc network routing Protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in a timely manner. Route construction should be done with a minimum of overhead and bandwidth consumption. This paper examines routing protocols for ad hoc networks and evaluates these Protocols based on a given set of parameters. In this work we compared three different types of routing protocols each under the following basic categories - Proactive, Reactive and Hybrid. A total ten different protocols are compared by presenting their characteristics and functionality with a highlight on their merits and drawbacks.

Keywords: MANET, routing protocol

1. Introduction

Mobile ad hoc networks (MANETs) are rapidly evolving as an important area of wireless communication. MANETs are infrastructure less and wireless in which there are several routers which are free to move arbitrarily and perform management of routes [1]. Ad-hoc wireless network do not need any infrastructure to work. Each node can communicate directly with other node so no access point controlling medium access is necessary. Infrastructure less networks, do not have fixed routers all the nodes in the network need to act as routers and all nodes are capable of movement and can be connected dynamically in an arbitrary manner. Mobile Ad hoc Networks (MANET) are example of infrastructure less network. In the ad hoc network shown in Figure 1.

MANET can have multiple hops over wireless links; also connection point to the internet may also change. It has to support multi hop paths for mobile nodes to communicate with each other. If mobile nodes are within the communication range of each other than source node can send message to the destination node otherwise it can send through intermediate node. Now-a-days mobile ad hoc networks have robust and efficient operation in mobile wireless networks as it can include routing functionality into mobile nodes which is more than just mobile hosts and reduces the routing overhead and saves energy for other nodes.

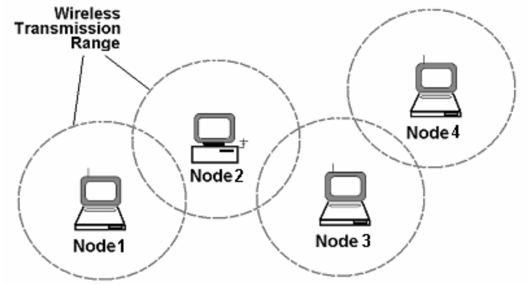

Fig 1: Mobile Ad Hoc Networks-MANETs.

Mostly mobile ad hoc networks are used in military communication by soldiers, planes, tanks etc, operations, automatic battlefields, emergency management teams to rescue, search, fire fighters or by police and replacement of a fixed infrastructure in case of earthquake, floods, fire etc, quicker access to patient data about record, status, diagnosis from the hospital database, remote sensors for weather, personal area network, taxi cab network, sports stadiums, mobile offices, yachts, small aircraft, electronic payments from anywhere, voting systems, vehicular computing, education systems with set-up of virtual classrooms, conference rooms, meetings, peer to peer file sharing systems, collaborative games with multi users.

Table 1: MANET Applications

Applications	Descriptions
Tactical Networks	▪ Military operations and battlefields
Sensor Networks	▪ Home applications that are context-aware; with embedded smart sensors in electronic appliances
	▪ Environmental applications include biological detection.
Emergency Operations	▪ Search and rescue for disaster recovery
	▪ Replacement of a fixed infrastructure in case of natural catastrophes
Commercial Usage	▪ E-commerce such as electronic payments made from anywhere
	▪ Vehicular services that include transmission of news, weather, audio/video clips and traffic conditions
Infotainment	▪ Multi-user online games
	▪ Outdoor Internet access
Location Aware Services	▪ Follow-on services such as automatic call-forwarding
Educational Tools	▪ Virtual classrooms or instantaneous conferences

1.1 Routing in MANET
Mobile ad hoc network's routing protocols are characteristically subdivided into three main categories. These are proactive routing protocols, reactive routing protocols and hybrid routing protocols. Each category has many protocols and some of these protocols are shown in Figure 2:

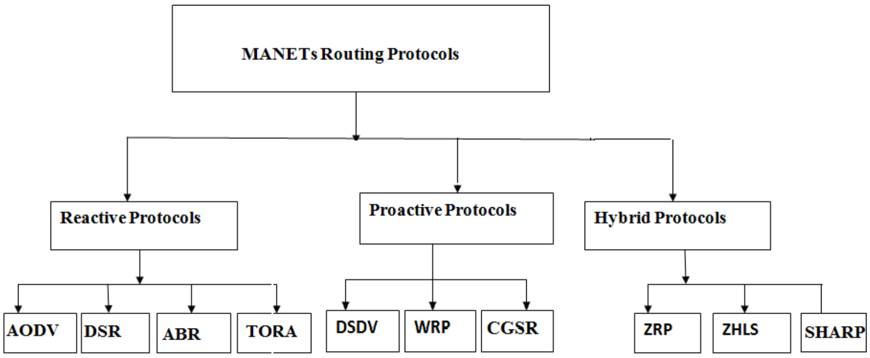

Fig 2: Classification of Routing Protocols

2. Reactive routing protocol
The reactive protocols don't maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet [2]. These protocols were designed to reduce the overhead encountered in proactive protocols by maintaining information for active routes only. This means that the routes are determined and maintained for the nodes that are required to send data to a particular destination.

2.1 Ad hoc on demand distance vector (AODV)
Ad hoc on demand distance vector protocol is reactive protocol. It constructs route on demand and aims to reduce routing load [3]. It uses a table driven routing framework, destination sequence numbers for routing packets to destination mobile nodes and has location independent algorithm. It sends messages only when demanded and it has bi-directional route from the source and destination. When it has packets to send from source to destinations mobile node then it floods the network with route request (RREQ) packets. All mobile nodes that receive the RREQ from neighbour or update message then it checks routing table to find out that if it is the destination node or if it has fresh route to the destination then it unicast route reply (RREP) which is routed back on a temporary reverse route generated by RREQ from source node, or else it re-broadcast RREQ. In order to reduce control overhead, a controlled flooding (CF) mechanism to reduce overlapped flooding messages for AODV is presented in [4].

2.2 Dynamic source routing (DSR)
Dynamic Source Routing (DSR) is an on demand, source based routing protocol. The sender knows the complete hop by hop route to the destination [5]. In the route discovery process, the network is flooded by the route request (RREQ) packets where each node receiving it rebroadcasts it, unless it is the destination. The addresses of intermediate nodes are enlisted on DSR RREQ and RREP control packets. The key feature of DSR is the use of source routing, which means the sender knows the complete hop-by-hop route to the destination. The two major phases of the protocol are route discovery and route maintenance. When the source node wants to send a packet to a destination, it looks up its route cache to determine if it already contains a route to the destination. If it finds that an unexpired route to the destination exists, then it uses this route to send the packet. But if the node does not have such a route, then it initiates the route discovery process by broadcasting a route request packet. The route request packet contains the address of the source and the destination, and a unique identification number. Each intermediate node checks whether it knows of a route to the destination. If it does not, it appends its address to the route record of the packet and forwards the packet to its neighbours. A route reply is generated when either the destination or an intermediate node with current information about the destination receives the route request packet.

2.3 Associativity-Based Routing (ABR)
The Associatively Based Routing (ABR) protocol checks the association between nodes and transfer the messages from sources to destinations. Association [6] is a concept that verifies the wireless connection between two nodes that actually involve in the procedure of transferring the packets. In ABR, a route is selected based on the degree of association stability of mobile nodes. Each node periodically generates an inspiration to signify its existence. When received by neighboring nodes, this inspiration causes their Associatively tables to be updated. Association stability is defined by connection stability of one node with respect to another node over time and space. A high degree of association stability may indicate a low state of node mobility, while a low degree may indicate a high state of node mobility. The three phases of ABR are: Route discovery, Route reconstruction and Route deletion.

2.4 Temporally Ordered Routing Algorithm (TORA)
The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive loop-free distributed routing algorithm based on the concept of link reversal [7]. TORA is proposed to operate in a highly dynamic mobile networking environment. It is source initiated and provides multiple routes for any desired source/destination pair. The key design concept of TORA is the localization of control messages to a very small set of nodes near the occurrence of a topological change. To accomplish this, nodes need to maintain routing information about adjacent (one-hop) nodes. The protocol performs three basic functions: route creation, route maintenance, and route removal.

3. Proactive routing protocols (PRP)

These protocols are also called as proactive protocols since they maintain the routing information even before it is needed [8]. Each and every node in the network 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. Many of these routing protocols come from the link-state routing. There exist some differences between the protocols that come under this category depending on the routing information being updated in each routing table. Furthermore, these routing protocols maintain different number of tables. The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth.

3.1 destination-sequenced distance-vector (DSDV)

The Destination-Sequenced Distance-Vector [9] Routing protocol is based on the idea of the classical Bellman-Ford Routing Algorithm with certain improvements such as making it loop-free. The DSDV is the foundation of many other distance vector routing protocols such as AODV that is addressed later. The distance vector routing is less robust than link state routing due to problems such as count to infinity. and bouncing effect. Consequently, the proactive routing protocols prefer link state routing because additional route calculation of link state routing doesn't contribute to delay. The data broadcast by each node will contain its new sequence number and the following information for each new route:

- The destination address,
- The number of hops required to reach the destination, and
- The new sequence number, originally stamped by the destination.

3.2 The wireless routing Protocol (WRP)

The Wireless Routing Protocol (WRP) described in [10] is a table-based protocol with the goal of maintaining routing information among all nodes in the network. Each node in the network is responsible for maintaining four tables:

- Distance table,
- Routing table,
- Link-cost table, and
- Message retransmission list (MRL) table.

Each entry of the MRL contains the sequence number of the update message, a retransmission counter, an acknowledgment-required flag vector with one entry per neighbour, and a list of updates sent in the update message. The MRL records which updates in an update message need to be retransmitted and which neighbours should acknowledge the retransmission [10]. Mobiles inform each other of link changes through the use of update messages. An update message is sent only between neighbouring nodes and contains a list of updates (the destination, the distance to the destination, and the predecessor of the destination), as well as a list of responses indicating which mobiles should acknowledge (ACK) the update.

Nodes learn of the existence of their neighbours from the receipt of acknowledgments and other messages. If a node is not sending messages, it must send a hello message within a specified time period to ensure connectivity. Otherwise, the lack of messages from the node indicates the failure of that link; this may cause a false alarm. When a mobile receives a hello message from a new node, that new node is added to the mobile's routing table, and the mobile sends the new node a copy of its routing table information.

3.3 Cluster Head gateway switch routing (CGSR)

The Cluster head Gateway Switch Routing (CGSR) protocol differs from the previous protocol in the type of addressing and network organization scheme employed. Instead of a "flat" network, CGSR is a clustered multihop mobile wireless network with several heuristic routing schemes [11]. A cluster head selection algorithm is utilized to elect a node as the cluster head using a distributed algorithm within the cluster. Using this method, each node must keep a "cluster member table" where it stores the destination cluster head for each mobile node in the network. These cluster member tables are broadcast by each node periodically using the DSDV algorithm. Nodes update their cluster member tables on reception of such a table from a neighbour. The disadvantage of having a cluster head scheme is that frequent cluster head changes can adversely affect routing protocol performance since nodes are busy in cluster head selection rather than packet relaying. Hence, instead of invoking cluster head reselection Every time the cluster membership changes, a Least Cluster Change (LCC) clustering algorithm are introduced.

4. Hybrid routing protocols (HRP)

The Ad Hoc network can use the hybrid routing protocols that have the advantage of both proactive and reactive routing protocols to balance the delay and control overhead (in terms of control packages). Hybrid routing protocols try to maximize the benefit of proactive routing and reactive routing by utilizing proactive routing in small networks (in order to reduce delay), and reactive routing in large-scale networks (in order to reduce control overhead).

The difficulty of all hybrid routing protocols is how to organize the network according to network parameters. The common disadvantage of hybrid routing protocols is that the nodes that have high level topological information maintains more routing information, which leads to more memory and power consumption [12].

4.1 Zone Routing Protocol (ZRP)

The Zone Routing Protocol [13] was the first hybrid routing protocol with both a proactive and a reactive routing component. The nodes have a routing zone, which defines a range that each node is required to maintain network connectivity proactively. Therefore, for nodes within the routing zone, routes are immediately available. For nodes that lie outside the routing zone, routes are determined on-demand and it can use any on-demand routing protocol to determine a route to the required destination. ZRP divides its network in different zones. That's the nodes local neighbourhood. Each node may be within multiple overlapping zones, and each zone may be of a different size. The size of a zone is not determined by geographical measurement. It is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone. The advantage of this protocol is that it has significantly reduced the amount of communication overhead when compared to pure proactive protocols.

4.2 Zone-based hierarchical link state protocol (ZHLS)

The Zone-Based Hierarchical Link State Protocol [14] is based on the GPS (Global Positioning System). ZHLS is similar to the Zone Routing Protocol. It is a hybrid routing protocol acting similar like ZRP. The protocol is proactive when the destination node is in the same zone as the node which sent the request. On the other hand, the protocol is reactive when the destination node isn't within the zone from the source node. But in ZHLS the network is divided in non-overlapping zones. Unlike other hierarchical protocol, there is no zone head. The zone size depend on node mobility, network density, transmission power and propagation characteristics. Each node only knows the connectivity within its zone and the zone connectivity of the whole network. The node knows its position and zone ID because of the Global positioning system. It can determine its zone ID by mapping its physical location to a zone map. This zone map has to be worked out at the design stage

4.3 Sharp hybrid adaptive routing Protocol (SHARP)

SHARP utilizes this fundamental trade off between proactive versus reactive routing to find a good balance between route information propagated proactively and route information that is left up to on demand discovery. SHARP utilizes both a proactive and a reactive protocol to perform routing. Each SHARP node determines the net-work neighbourhood, called *proactive zone*, in which routing information pertaining to itself is disseminated proactively. SHARP relies on a novel proactive routing algorithm that is both efficient and analytically tractable. However, SHARP can use any reactive routing algorithm whose costs can be characterized analytically. SHARP finds the "sweet spot" between the two routing regimes by dynamically adjusting the extent of proactive and reactive routing. This boundary is determined by an analytical model and guided by dynamically-performed empirical measurements from the physical network. SHARP enables each application to pursue different quantitative metrics for guiding the inherent trade-off between increased overhead for proactive information dissemination versus reduced latency and loss rate. Each SHARP node can separately pursue different application-specific performance guarantees. For instance, one node may direct SHARP to adjust its route dissemination to reduce delay jitter, while another node concurrently uses SHARP to minimize packet overhead.

An adaptive hybrid routing protocol requires the following three properties for successful deployment.

Adaptive: The protocol should be applicable to a wide range of network characteristics. It should automatically adjust its behaviour to achieve target goals in the face of changes in traffic patterns, node mobility and other network characteristics.

Flexible: The protocol should enable applications to optimize for different application-specific metrics at the routing layer. These optimization goals should not be set by the network designer, but be placed under the control of the network participants.

Efficient and Practical: The protocol should achieve better performance than pure, non-hybrid, strategies without invoking costly low-level primitives such as those for distributed agreement or reliable broadcast. Through a combination of protocol design, model, and mechanisms, SHARP's hybridization approach provides all of these properties.

5. Comparison

The following section provides comparison of the previously described routing algorithms. That is compares table-driven protocols, as well as compares on-demand protocols and hybrid protocols. Based on set of parameters (Routing metric, Routing philosophy, Loop free and Multicast capable.

Table 2: Comparison of routing protocols

Parameters	AODV	DSR	ABR	TORA	DSDV	WRP	CGSR	ZRP	ZHLS	SHARP
Routing metric	Fresh and Shortest path	Shortest path	Associativity and Shortest path and others	Shortest path	Shortest path	Shortest path	Shortest path	Zone based	Zone based	Soft point
Routing philosophy	Flat	Flat	Flat	Flat	Flat	Hierarchical	Flat	Flat	Flat	Flat
Loop-free	Yes	Yes	Yes	Yes	Yes	Yes, but not instantaneous	Yes	Yes	Yes	Yes
Multicast capability	Yes	No	No	No	No	No	No	No	No	No

6. Conclusion

In this paper we provide a review of several routing schemes proposed for ad hoc mobile networks. We also provide a classification of these schemes according to the routing strategy (i.e., table-driven and on-demand, Hybrid). We have presented a comparison of these three categories of routing protocols, highlighting their features, differences, and characteristics. Finally, we have identified possible applications and challenges facing ad hoc mobile wireless networks. 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. The field of ad hoc mobile networks is rapidly growing and changing, and while there are still many challenges that need to be met, it is likely that such networks will see widespread use within the next few years.

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