Intelligent Routing Protocols for Mobile Ad Hoc Network

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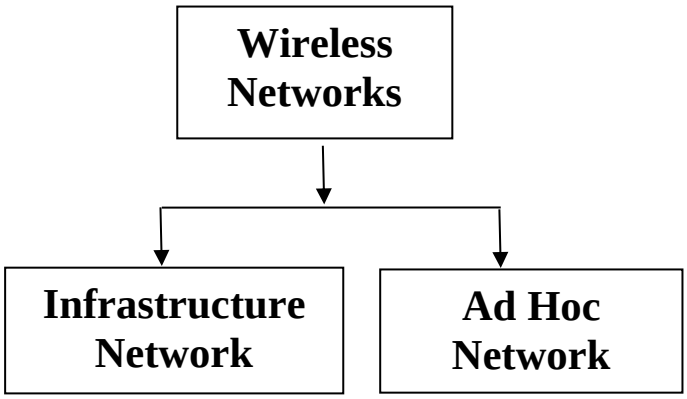
Abstract- *In recent years mobile ad hoc networks have become very popular and lots of research is being done on different aspects of MANET. Mobile Ad Hoc Networks (MANET) is a system of mobile nodes like laptops, sensors, etc interfacing without the centralized infrastructure (access points, bridges, etc.). A Mobile Ad hoc Network (MANET) is a collection of independent self organized nodes. There are different aspects which are taken for research like routing, synchronization, power consumption, bandwidth considerations etc. Routing on ad hoc network has become a major research issue due to it's increasing complexity and the rush of challenging problems. There are different routing protocols proposed for MANETs which makes it pretty difficult to determine which protocol is suitable for different network conditions. As promising network type in future mobile applications, mobile Ad hoc networks are attracting more and more researchers. This paper gives the up to date review and a comparative analysis of related routing protocols from analysis point of view for mobile Ad hoc network.*

Keywords- MANETs; Distributed Protocols; On Demand Protocols; Clustered Gateway Switch Routing(CGSR); Destination Sequenced Distance Vector Routing Protocol(DSDV); Optimal Link State Routing protocol(OLSR); Ad Hoc On Demand Distance Vector Routing Protocol(AODV); Signal Stability Based Adaptive Routing Protocol(SSA); Zone Routing Protocol(ZRP); Hybrid Ad hoc Routing Protocol(HARP); Sharp Hybrid Adaptive Routing Protocol(SHARP)

I. INTRODUCTION

Ad hoc wireless networks use multi hop radio relaying and manage without support of any fixed infrastructure. This makes the routing complex compared to other networks. A node can transmit and receive data. It is also act as a router for routing packets for other nodes. A node forwards packet in an ad hoc network using the routing algorithms [1-7]. A challenge for the ad hoc routing protocols is Attack. Some of the attacks are modification, manufacture, tunnelling attack, black hole attack, denial of service attack, invisible node attack, Sybil attack, rushing attack and non cooperation. Some secured routing protocols are developed to short out the attacks like Ariadne[1], ARAN (Authenticated Routing for Ad hoc Networks)[2,3], SEAD (Secure Efficient Ad hoc Distance vector routing)[4], SRP (Secure Routing Protocol)[5] etc.

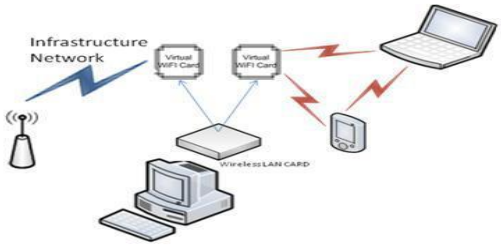
Wireless networks provide connection flexibility between users in different places. Moreover, the network can be extended to any place or building without the need for a wired connection. Wireless networks are classified into two categories – 1. Infrastructure networks and 2. Ad Hoc networks [2] as shown in Figure 1.



[Figure. 1 : Classification of Wireless Networks]

Infrastructure networks

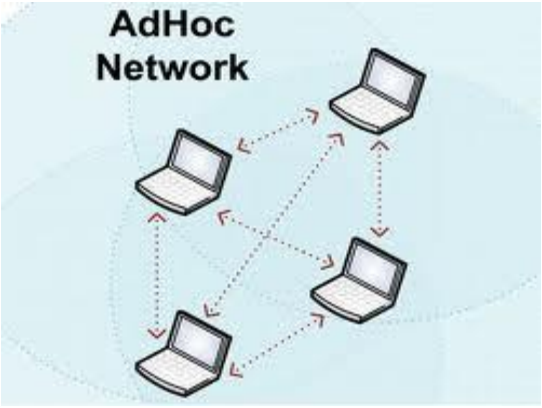
An Access Point (AP) represents a central coordinator for all nodes. Any node can be joining the network through AP. In addition, AP organizes the connection between the Basic Set Services (BSSs) so that the route is ready when it is needed. However, one drawback of using an infrastructure network is the large overhead of maintaining the routing tables. Infrastructure network is same as shown in Figure 2.



[Figure. 2 : Infrastructure Network]

Ad Hoc networks

A wireless ad hoc network is a decentralized type of wireless network. The network is ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks [1]. Ad Hoc networks do not have a certain topology or a central coordination point. Therefore, sending and receiving packets are more complicated than infrastructure networks. Figure 3 illustrates an Ad Hoc network.



[Figure. 3: Ad Hoc Network]

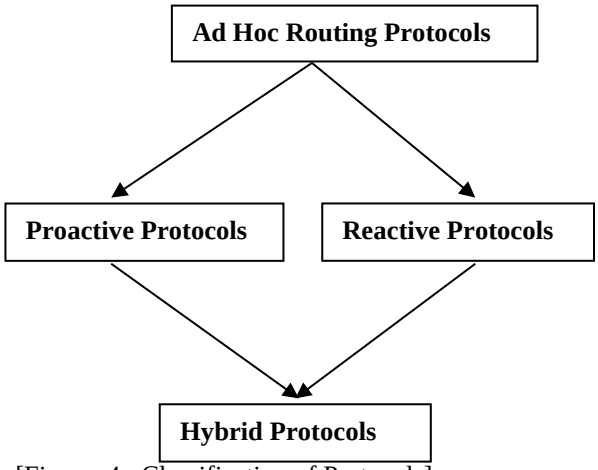
II. CHARACTERISTICS OF MANET

Mobile ad hoc network nodes are furnished with wireless transmitters and receivers using antennas, which may be highly directional (point to point), unidirectional (broad cast), some combination. At a given point in time, depending on positions of nodes, their transmitter and receiver coverage patterns, communication power levels and co channel interference levels, a wireless connectivity in the form of a random, multi hop graph or "ad hoc" network exists among the nodes. This ad hoc topology may modify with time as the nodes move or adjust their transmission and reception parameters [6]. The characteristics of these networks are summarized as follows:

- Nodes can perform the roles of both hosts and routers.
- Bandwidth-constrained, variable capacity links.
- Energy-constrained Operation.
- Limited Physical Security.
- Dynamic network topology.
- Frequent routing updates.

III. CLASSIFICATION OF ROUTING PROTOCOLS

Routing protocols define a set of rules which governs the journey of message packets from source to destination in a network. In MANET, there are different types of routing protocols each of them is applied according to the network circumstances. Figure 4 shows the basic classification of the routing protocols in MANETs [1].



[Figure. 4 : Classification of Protocols]

3.1 Proactive Routing Protocols

Proactive routing protocols are also called as table driven routing protocols. In this every node maintain routing table which contains information about the network topology even without requiring it [2]. This feature although useful for datagram traffic, incurs substantial signalling traffic and power consumption [12]. The routing tables are updated periodically whenever the network topology changes. Proactive protocols are not suitable for large networks as they need to maintain node entries for each and every node in the routing table of every node [13]. These protocols maintain different number of routing tables varying from protocol to protocol. There are various well known proactive routing protocols.
Example: DSDV, OLSR, WRP etc.

(i) Destination-Sequenced Distance Vector Routing Protocol (DSDV)
DSDV is developed on the basis of Bellman Ford routing [15] algorithm with some modifications. The DSDV was developed by Perkins and Bhagwat in 1994 [2]. The main feature of DSDV is its ability of solving problems of loops within the network. 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. DSDV protocol requires each mobile node in the network to advertise its own routing table to its current neighbours. The advertisement is done either by

broadcasting or by multicasting. By the advertisements, the neighbouring nodes can know about any change that has occurred in the network due to the movements of nodes. 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 neighbours, where as in case of incremental update, only the entries that require changes are sent [6].

ii) Wireless Routing Protocol (WRP)

Wireless Routing Protocol is a proactive unicast routing mechanism for mobile ad-hoc networks (MANETs). WRP uses an enhanced version of the distance vector routing protocol[15]. The wireless routing protocol, similar to DSDV, inherits the properties of the distributed Bellman Ford algorithm. WRP belongs to the general class of path-finding algorithms [14, 16, 17], 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: 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 neighbours of a node. The nodes in the response list of update message (which is formed using MRL) should send acknowledgments. If there is no change from the last update, the nodes in the response list should send an idle Hello message to ensure connectivity. A node can decide whether to update its routing table after receiving an update message from a neighbour and always it looks for a better path using the new information. If a node gets a better path, it relays back that information to the original nodes so that they can update their tables. After receiving the acknowledgment, the original node updates its MRL. Thus, 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 [6].

iii)Cluster Gateway Switch Routing Protocol (CGSR)

CGSR considers a clustered mobile wireless network instead of a flat network [18]. For structuring the network into separate but interrelated groups, cluster heads are elected using a cluster head selection algorithm. 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. CGSR uses DSDV protocol as the underlying routing scheme and hence, it has the same overhead as DSDV. However, it 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 [6].

iv) Optimal Link State Routing protocol (OLSR)

OLSR (Optimal Link State Routing) protocol provides a more organized and efficient way to manage traffic control packets between two nodes based on a shortest path strategy [10]. As a proactive protocol, OLSR periodically exchange information among nodes in order to acquaint itself the network status. Consequently the routing tables of network nodes are maintained constantly updated with link state messages. However, the protocol limits the number of nodes that are allowed to forward link state messages in order help to preserve high network through- put. The technique employed for this limitation is called MPR (Multi Point Relay), by which a link state message is sent by piggyback over hello messages as far as 2 hops from the source MPR node and therefore preventing network flooding. Note that through MRP the number of nodes allowed to retransmit control packets is limited.

3.2) Reactive Routing Protocols

Reactive routing protocol is also known as on demand routing protocol. In this protocol route is discovered whenever it is needed Nodes initiate route discovery on demand basis. Source node sees its route cache for the available route from source to destination if the route is not available then it initiates route discovery process. The on- demand routing protocols have two major components [7]:

Route discovery:

In this phase source node initiates route discovery on demand basis. Source nodes consults its route cache for the available route from source to destination otherwise if the route is not present it initiates route discovery. The source node, in the packet, includes the destination address of the node as well address of the intermediate nodes to the destination.

Route maintenance:

Due to dynamic topology of the network cases of the route failure between the nodes arises due to link breakage etc, so route maintenance is done. Reactive protocols have acknowledgement mechanism due to which route maintenance

is possible Reactive protocols add latency to the network due to the route discovery mechanism. Each intermediate node involved in the route discovery process adds latency. These protocols decrease the routing overhead but at the cost of increased latency in the network. Hence these protocols are suitable in the situations where low routing overhead is required. There are various well known reactive routing protocols present in MANET for example DSR, AODV, TORA and LMR [1].

i) Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) is a reactive protocol based on the source route approach [9]. Dynamic Source Routing is an on demand protocol similar to AODV. In other word, each node along the path receives directly from the source node all necessary routing instruction. There many improved versions of DSR, including DSRFLOW [12]. In Dynamic Source Routing (DSR), the protocol is based on the link state algorithm in which source initiates route discovery on demand basis. The sender determines the route from source to destination and it includes the address of intermediate nodes to the route record in the packet. DSR was designed for multi hop networks for small Diameters. It is a beaconless protocol in which no HELLO messages are exchanged between nodes to notify them of their neighbours in the network [2].

ii) Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV is basically an improvement of DSDV[10]. But, AODV is a reactive routing protocol instead of proactive. It minimizes the number of broadcasts by creating routes based on demand, which is not the case for DSDV. When any source node wants to send a packet to a destination, it broadcasts a route request (RREQ) packet. The neighbouring nodes in turn broadcast the packet to their neighbours and the process continues until the packet reaches the destination. During the process of forwarding the route request, intermediate nodes record the address of the neighbour from which the first copy of the broadcast packet is received. This record is stored in their route tables, which helps for establishing a reverse path. If additional copies of the same RREQ are later received, these packets are discarded. The reply is sent using the reverse path. For route maintenance, when a source node moves, it can reinitiate a route discovery process. If any intermediate node moves within a particular route, the neighbour of the drifted node can detect the link failure and sends a link failure notification to its upstream neighbour. This process continues until the failure notification reaches the source node. Based on the received information, the source might decide to re initiate the route discovery phase [6].
iii)Associativity-Based Routing (ABR)

Associatively-Base Routing (ABR) was invented and developed by C. K. Toh at the Cambridge University in1996. It is a source-initiated routing protocol, that is, it does not need periodic route updating. ABR protocol defines a new type of routing metric “degree of association stability” for mobile ad hoc networks [11]. In this routing protocol, a route is selected based on the degree of association stability of mobile nodes. Each node periodically generates beacon to announce its existence. Upon receiving the beacon message, a neighbour node updates its own associativity table. For each beacon received, the associativity tick of the receiving node with the beaconing node is increased. A high value of associativity tick for any particular beaconing node means that the node is relatively static. Associativity tick is reset when any neighbouring node moves out of the neighbourhood of any other node [6]. A fundamental objective of ABR is to find longer lived routes. ABR consists of 3 operational phases: Route Discovery, Route Repair/Reconstruction and Route Delete. A detailed description of these operations is given in [12].

iv) Signal Stability–Based Adaptive Routing Protocol (SSA)

SSA protocol focuses on obtaining the most stable routes through an ad hoc network [19]. The protocol performs on demand route discovery based on signal strength and location stability. Based on the signal strength, SSA detects weak and strong channels in the network. SSA can be divided into two cooperative protocols: the Dynamic Routing Protocol (DRP) and the Static Routing Protocol (SRP). DRP uses two tables: Signal Stability Table (SST) and Routing Table (RT). SST stores the signal strengths of the neighbouring nodes obtained by periodic beacons from the link layer of each neighbouring node. These signal strengths are recorded as weak or strong. DRP receives all the transmissions and, after processing, it passes those to the SRP. SRP passes the packet to the node’s upper layer stack if it is the destination. Otherwise, it looks for the destination in routing table and forwards the packet. If there is no entry in the routing table for that destination, it initiates the route finding process. Route request packets are forwarded to the neighbours using the strong channels. The destination, after getting the request, chooses the first arriving request packet and sends back the reply. The DRP reverses the selected route and sends a route-reply message back to the initiator of route request. The DRPs of the nodes along the path update their routing tables accordingly. In case of a link failure, the intermediate nodes send an error message to the source indicating which channel has failed. The source in turn sends an erase message to inform all nodes about the broken link and initiates a new route-search process to find a new path to the destination [6].

v) Temporarily Ordered Routing Algorithm (TORA)

TORA [20] is a reactive routing protocol with some proactive enhancements where a link between nodes is established creating a Directed Acyclic Graph (DAG) of the route from the source node to the destination. This protocol uses a link reversal model in route discovery. A route discovery query is broadcasted and propagated throughout the network until it reaches the destination or a node that has information about how to reach the destination. TORA defines a parameter, termed height. Height is a measure of the distance of the responding node's distance up to the required destination node. In the route discovery phase, this parameter is returned to the querying node. Temporally Ordered Routing Algorithm [13] attempts to achieve a high degree of scalability using a "flat", non hierarchical routing mechanism.

vi) Lightweight Mobile Routing Protocol (LMR)

Lightweight Mobile Routing Algorithm [5], an on-demand routing protocol belongs to the class of link reversal algorithms. The LMR algorithm was developed for routing in highly dynamic mobile networks. If the mobility is extremely high, the only possible routing strategy is flooding the network with a message and hoping that the message will eventually reach the destination. On the other hand, if mobility is low, shortest path based algorithms are more appropriate as shortest path computations converge before the nodes move. The LMR algorithm is suitable in an intermediate domain when mobility is not so low that shortest path algorithms can converge, and mobility is not so high that flooding is the only possibility. The LMR algorithm is loosely based on the link reversal strategy of the Gafni-Bertsek as algorithm [6].

3.3) Hybrid Routing Protocol

There is a trade off between proactive and reactive protocols. Proactive protocols have large overhead and less latency while reactive protocols have less overhead and more latency. So a Hybrid protocol is presented to overcome the shortcomings of both proactive and reactive routing protocols. Hybrid routing protocol is combination of both proactive and reactive routing protocol. It uses the route discovery mechanism of reactive protocol and the table maintenance mechanism of proactive protocol so as to avoid latency and overhead problems in the network. Hybrid protocol is suitable for large networks where large numbers of nodes are present. In this large network is divided into set of zones where routing inside the zone is performed by using reactive approach and outside the zone routing is done using reactive approach. There are various popular hybrid routing protocols for MANET like ZRP, SHARP [2]

i)Zone Routing Protocol (ZRP)

ZRP [21] is suitable for wide variety of MANETs, especially for the networks with large span and diverse mobility patterns. In this protocol, each node proactively maintains routes within a local region, which is termed as routing zone. Route creation is done using a query reply mechanism. For creating different zones in the network, a node first has to know who its neighbours are. A neighbour is defined as a node with which direct communication can be established, and that is, within one hop transmission range of a node. Neighbour discovery information is used as a basis for Intra zone Routing Protocol (IARP), which is described in detail in [22]. Rather than blind broadcasting, ZRP uses a query control mechanism to reduce route query traffic by directing query messages outward from the query source and away from covered routing zones. A covered node is a node which belongs to the routing zone of a node that has received a route query. During the forwarding of the query packet, a node identifies whether it is coming from its neighbour or not. If yes, then it marks all of its known neighbouring nodes in its same zone as covered [2]. The query is thus relayed till it reaches the destination. The destination in turn sends back a reply message via the reverse path and creates the route.

Parametric Comparison

Parameters	Reactive protocol	Proactive protocol	Hybrid protocol
Routing philosophy	Flat	Flat/Hierarchical	Hierarchical
Routing scheme	On demand	Table driven	Combination of both
Routing overhead	Low	High	Medium
Latency	High due to flooding	Low due to routing tables	Inside zone low outside similar to Reactive protocols
Scalability level	Not suitable for large networks	Low	Designed for large networks
Availability of routing information	Available when required	Always available stored in tables	Combination of both
Periodic updates	Not needed as route available on demand	Yes. Whenever the topology of the network changes	Yes needed inside the zone
Storage capacity	Low generally Depends upon the number of routes	High ,due to the routing tables	Depends on the size of Zone, inside the zone sometimes high as proactive protocol
Mobility support	Route maintenance	Periodical updates	Combination of both

[Figure 5 : Parametric Comparison]

ii)Sharp Hybrid Adaptive Routing Protocol (SHARP)

SHARP [23] adapts between reactive and proactive routing by dynamically varying the amount of routing information shared proactively. This protocol defines the proactive zones around some nodes. The number of nodes in a particular proactive zone is determined by the node-specific zone radius. All nodes within the zone radius of a particular node become the member of that particular proactive zone for that node. If for a given destination a node is not present within a particular proactive zone, reactive routing mechanism (query reply) is used to establish the route to that node. Proactive routing mechanism is used within the proactive zone. Nodes within the proactive zone maintain routes proactively only with respect to the central node. In this protocol, proactive zones are created automatically if some destinations are frequently addressed or sought within the network. The proactive zones act as collectors of packets, which forward the packets efficiently to the destination, once the packets reach any node at the zone vicinity [2].

IV. CONCLUSION

We have seen a great development in the field of wireless networks (infrastructure based) and in the field of Mobile ad hoc network (infrastructure less network).In this paper a number of routing protocols for MANET, which are broadly categorized as proactive and reactive and Hybrid protocols has been presented. The effort has been made on the comparative study of Reactive, Proactive and Hybrid routing protocols has been presented. One of the advantages of proactive protocols on ad hoc networks (OLSR) is no need for central management to handle the routing process in contrast to regular and permanent routing tables required by those table driven protocols. On demand protocols can be highly interesting if a network is mainly broadcasting one. In this case, on demand protocols can provide higher throughput. There are various shortcomings in different routing protocols and it is difficult to choose routing protocol for different situations as there is swapping between various protocols. There are various challenges that need to be met, so these networks are going to have common use in the future.

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