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Ant Colony based and Mobile Ad Hoc Networks Routing Protocols: a Review

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ABSTRACT
Mobile ad-hoc networks (MANETs) are the wireless ad-hoc networks which enclose sovereign group of wireless mobile nodes. The communication is relayed via routes which are discovered using various routing protocols. Diverse routing protocols have been proposed so far in MANETs. Likewise, swarm intelligence (SI) based ant colony optimization (ACO) technique have various routing protocols which can also solve the routing problems in MANETs. ACO uses the chemical substance called Pheromone whose value is stored in pheromone table to find shortest path between source and destination. However our exigent task is to select optimal routing protocol for changeable network scenarios. This paper stated the functioning of existing ACO based ad-hoc routing protocols as well as ad-hoc routing protocols for MANETs and the comparison tables with summery of every protocol is shown. Moreover this review will help researchers in having glimpse of the existing protocols and thus can select optimal routing protocol which responds quickly on change of network topology.

Keywords
MANETs, DSDV, AODV, ACO, DSR

1. INTRODUCTION
1.1Mobile ad hoc network (MANETs)
Mobile Ad Hoc network (MANETs) refers to a network which is self-organized and multi-hope having mobile nodes operating in a distributed manner without help of any central infrastructure. MANETs possess characteristics such as bandwidth constrained, energy constrained, limited physical security and dynamic network topology etc. At one time the node is in their domain and after sometime that node changes their domain, causes change in topology of networks. Hence the major issue related to MANETs is routing. In MANETs communication is performed via the wireless means and the nodes can perform the roles of both hosts as well as routers for the routing of packets in the network. As a result of limited bandwidth of nodes, the source and destination may have to communicate via intermediate nodes [1]. As in multi-hop routing, the nodes are forwarding packets to each other which require some sort of routing protocol to take the routing decisions. Figure1 shows a mobile ad-hoc network with 4 nodes in which first node can communicate with last node via second and third intermediate nodes, and vice versa. Many routing protocols for MANETs have been proposed, but few comparisons between the different protocols have been made.

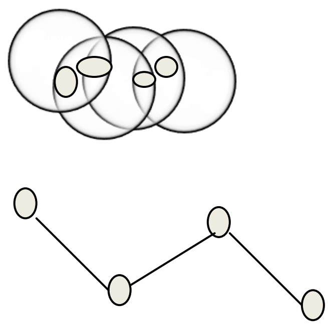

Figure1 Mobile Ad Hoc network

1.1 Ant Colony Optimization (ACO)
Ant Colony Optimization (ACO) [2] is general purpose optimization technique which is based on foraging behavior of ant species in real life. These real life ants walking to and from a food source, deposit a chemical substance called pheromone which establish the shortest path for other members of colony to be followed. Similarly in ACO, artificial ants are the agents which are used to solve the various optimization problems. These agents (ants) moving around in the network from one node to the other, updating routing tables (called pheromone table) of the nodes that they visit with what they have learned in their traversal so far. Afterwards agents selecting best shortest path from updated pheromone table.
While comparing MANETs and ANTS in Table 1 [3] we come to conclusion that though they have similarities like same physical structure, self-configuration and self-organization but still distinguished from each other in the route foundation, overhead, motive, routing table information.

Table 1: Comparison between MANETs and ANTS

Parameters	MANETs	ANTS
Overhead	More	Less
Packet Delivery Ratio	Less	More
Route Discovery Procedure	Route Request/Reply message are used	Pheromone value is used
Motive	Find shortest path for routing	To provide definite shortest path
Path Discovered	Single path, partially multipath	Multipath

2. CLASSIFICATION OF AD- HOC ROUTING PROTOCOLS

Many protocols have been developed for adhoc mobile networks ,which include more link failures, high power consumption, and high packet dropping ratio. As these routing protocols may generally be categorized as :

- **Table-driven :** In this approach, we forward the packets irrespetive of when and how routes are desired as there is always the availability of the routes in the continuously updated routed tables.
- **Source-initiated (on-demand):** In this approach, when a route is desired we use Query-Reply procedure to find routes to the destination and nodes have to wait till route is discovered.

Ad hoc Routing Protocols were classified as follows:

- Proactive Protocols
- Reactive Protocols
- Hybrid Protocols

The Figure 2 describes the three classifications of Ad hoc routing protocols and various protocols proposed under each category [4, 5, and 6].

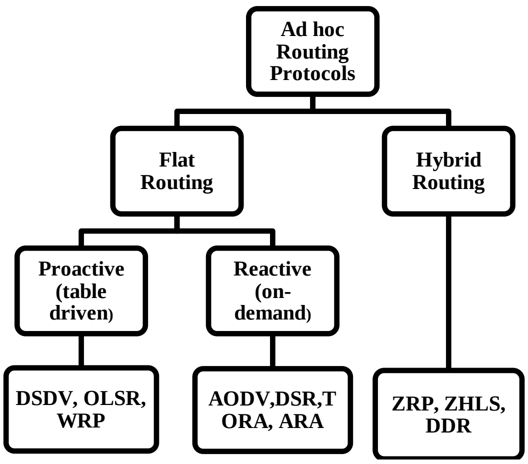

Figure2 Classification of Ad hoc Routing Protocols

3. PROACTIVE (TABLE- DRIVEN) PROTOCOLS IN MANETs

In these protocols each node contains number of different routing tables which maintain routing information to every other node in the network. These tables are updated if the network topology changes. Thus, when there is a requirement for a route, such route information is available immediately [4]. Different protocols in this table-driven category keep track of different routing state information [5]. So, the difference between these protocols exists in the way the routing information is updated and type of information kept in routing tables during routing. In these protocols a gratuitous overhead to maintain the routing tables may be generated, as every time topology changes so the nodes information has to be updated. This kind of protocol is usually very effective in those networks where nodes mobility rate is low. Varieties of proactive protocols are proposed so far namely DSDV [7], OLSR [8], WRP [9], STAR [10], and CGSR [11]. Some proactive protocol such as Dynamic Destination Sequenced Distance-Vector Routing Protocol (DSDV) [5, 7] and Wireless Routing Protocol (WRP) [4, 7] are described below to illustrate proactive protocols in detail.

3.1 DSDV

Charles E.Perkins and Pravin Bhagwat introduced Destination-Sequenced Distance-Vector (DSDV), one of the Ad hoc routing protocols [7]. It removes the looping problem which was incurred in Bell-Ford routing algorithm. Each node maintains the routing table in which all of possible destinations within the network and number of routing hops to each destination are recorded. The sequence number is important parameter of DSDV, used to allow mobile hosts to distinguish old routes from new ones. Updations found in the routing table are sent periodically throughout the network to maintain the consistency. It uses two types of route update packets to avoid overhead in network. One among the two is "full dump" packet which carries all the available routing information suitable for high mobility network and the other is "incremental packet" suitable for stable network, carries only that information changed since the last full dump [7] and discover new route using this changed information. During that two updates which have same sequence number then the route with the smaller hop count is used. Though this is a simple and routing loop free protocol but sometimes it doesn't fit in large networks since it uses most of the network bandwidth in the updating procedure.

3.2 WRP

Murthy and Garcia-Luna-Aceves propose Wireless Routing Protocol (WRP) which uses distributed Bellman-Ford algorithm [9]. Its prime goal is to maintain routing information among all the nodes in the network. Each node in network is responsible for maintaining 4 tables and these are the Distance Table, Routing Table, Link Cost Table, and Message Retransmission List (MRL) Table. The MRL table contains the sequence number of the update message, a retransmission counter (how often a message is retransmitted before the connection is rebuild) and a list of updates sent in the update message [9]. To improve reliability in delivering update messages, every neighbor is required to send ACKs for each update packet received. When no update messages have to be sent this protocol periodically exchanges empty "HELLO" messages. When no "HELLO" message was received in a specified time period then it has to be checked if the link is still reachable. If the node receives a "HELLO" message from a new node, the node is added to the routing table. The four routing tables cause memory overhead and to ensure the connectivity we have to use "HELLO" messages. It follows path finding algorithm which resolves the problem of count-to-infinity with consistency check which is performed by each node on predecessor information reported by its entire neighbor. It provides faster route convergence when a link failure in network occurs.

3.3 Summary

The chief difference between DSDV and WRP is the number of routing tables they exhibit and the way of updating routing tables that is DSDV uses full dump and incremental packet whereas WRP uses HELLO messages. Proactive protocols have some pros and cons like routing information is available all the time but on the other hand too much data stored which at the time of link failure causes late recovery of the tables. Other differences are presented in the Table 2 [4, 12] given below.

Table 2: Difference of DSDV and WRP Proactive Protocols

Parameters	DSDV	WRP
Number of Routing Table	2	4
Rate of Updations	Periodic and as required	Highly Periodic (HELLO messages)
Features	Exhibit no loop	No loop formation
Caching Overhead	Medium	High

4. REACTIVE (ON-DEMAND) PROTOCOLS

Reactive protocols are elected when we want to setup routes on demand. This route will be established by the routing protocol in the situation when any node wants to initiate the communication with another node to which it has no route. This type of protocol is generally based on flooding the network with Route Request (RREQ) and Route Reply (RREP) messages. To discover the route from source to destination we will use RREQ and as the destination node gets a RREQ message it sends RREP message for the confirmation of that route has been established. This kind of protocol is usually very effective for high mobility networks. It minimizes the number of hops of the selected path. They reduce the overhead by maintaining information for active routes only at the expense of delay due to route search. Some reactive protocols namely AODV [13], TORA [14], DSR [15], DYMO [16] are the existing reactive protocols available among which are Ad Hoc On-Demand Distance Vector Routing Protocol (AODV) [5, 12, and 13] and Dynamic Source Routing Protocol (DSR) [12, 15] described as below.

4.1 AODV

The Ad hoc On-demand Distance Vector (AODV) [13] routing protocol was developed by Perkins and Royer as an improvement to the DSDV routing algorithm. AODV [12] uses sequence number procedure from DSDV and Route Discovery procedure from DSR. AODV builds routes using a route request/route reply query packets. It uses three control packets for Route Discovery and Route Maintenance, namely RREQ (route request), RREP (route reply) and RERR (route error). When source wants to send a data packet to destination then source nodes first checks its routing table for the route to that destination is present or not. If the route is not present then Route Discovery procedure is applied and RREQ packet is broadcast to its neighbor who forward this packet onwards till destination is found. Nodes keep track of RREQ’s source IP address and broadcast ID. If they receive a RREQ which they have already processed, then they discard RREQ to avoid the duplicity. If node has a route to destination or it is a destination then it unicast a RREP with destination IP address and sequence number back to the source. During Route Maintenance, when the node is active but the links go down or destination moves away then RREP packet is send to each of its upstream neighbors to ensure the deletion of that link of the route. Once the message reaches to source node, it again starts Route Discovery process only if this route is still needed [4]. AODV is adaptable to highly dynamic networks [12].

4.2 DSR

The Dynamic Source Routing Protocol (DSR) [15] designed by D.B.Johnson, Maltz and Broch, for the use in multi-hop wireless ad hoc networks. It is based on the concept of source routing that is sender knows complete hop-by-hop route to destination and this protocol consists of Route Discovery and Route Maintenance procedures. The difference from AODV is that in DSR every node maintains route caches containing of multiple routes, which means source node can check whether valid route is found in the cache or not and if route exist then there is no requirement for Route Discovery. Route cache entries are continually updated as new routes are discovered. The other distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address which means AODV has less routing overhead than DSR. DSR is beneficial for low mobility network and also conserve power of nodes as in DSR no need of hello message exchange, therefore node can enter sleep mode [12].

4.3 Summary

Reactive protocols achieve the bandwidth advantage over proactive protocols. But at the same time reactive protocols lack in finding routes with in a lesser amount of time as routes are created on demand. AODV gives better throughput with low caching overhead with respect to DSR which provides multiple routes per destination as compared to former one. Comparison between AODV and DSR are presented in the Table 3 [4, 12] given below.

Table 3: Difference of AODV and DSR Reactive Protocols

Parameters	AODV	DSR
Source Routing	No	Yes
Time Relay	Does relay	Doesn’t relay
Path Discovered	Single route	Multiple routes
Periodic Broadcast	Yes(HELLO message)	No
Routing Overhead	Less	More
Route Storage Structure	Routing Table	Route Cache
Benefit	Adaptable to highly dynamic network topologies	Multiple Routes
Caching Overhead	Low	High

5. HYBRID PROTOCOLS

Hybrid Protocols are the outcome of Proactive and Reactive protocols. Hybrid protocols introduced to provide higher scalability than reactive or proactive protocols. In hybrid protocol we define zones as “intrazone” and “interzone” which attempt to minimize the number of re-broadcasting nodes. The intrazone routing is performed proactively and interzone routing is carried out reactively. Some examples of hybrid protocols are ZRP [17], ZHLS [18], CEDAR [19], DDR [20], DST [21] and we will discuss Zone Routing Protocol (ZRP) [12, 17, and 22] and Zone-Based Hierarchical Link State (ZHLS) [4, 12, and 18].

5.1 ZRP

The Zone Routing Protocol (ZRP) [17] designed by Haas and Pearlman. It combines the advantages of both proactive and reactive routing. ZRP divides its network into different zones which defines specific range for the nodes. Nodes within one zone called intrazone uses proactive approach for the routing to speed up communication among neighbors. And the nodes which recite outside the zone, routes are determined reactively. Thus it has reduced the delay of reactive protocols by allowing routes to be discovered rapidly [12]. Each node may be within multiple overlapping zones, and each zone may be of different size. The major concern in this routing protocol is to find out the size of the zone but by using Independent Zone Routing (IZR) which can allow adaptive and distributed reconfiguration of the optimized size of zone [22].

5.2 ZHLS

Zone-Based Hierarchical Link State (ZHLS) Protocol [4, 18] designed by Joa-Ng and Lu. It simplify the routing by dividing the topologies on two levels namely node level and zone level topology with no cluster heads. Each node has a node ID and zone ID calculated with the help of location tool GPS (Global Positioning System). Source node on transmission of data packets will first checks its intra-zone routing table and if the destination recites in its zone then the routing information are already present, no need for broadcasting. When the destination is in other zone then source node broadcast zone-level location request with node ID, Zone ID pair to all other zones and as destination got this request, it replies with the path. Hence ZHLS generates low overhead as compared to flooding approach in reactive protocols. Also because of the node ID, zone ID pair which is required for routing to destination node, routing path is adaptable to the changing topology [12].

5.3 Summary

Hybrid protocols take advantage of best of reactive and proactive protocols. Its goal is to initiate route-discovery on-demand but at limited search cost. The Table 4 [4, 5] will describe the differences between two hybrid protocols that are ZRP in which zones are usually defined based on hop count whereas in ZHLS zone is based on physical location.

Table 4: Difference of ZRP and ZHLS Hybrid Protocols

Parameters	**ZRP**	**ZHLS**
Routes Available	Single route	Multiple route
Route Reconstruction	At failure point	Sent the location request
Beacons	Yes	No
Routing	Flat Routing	Hierarchical Routing
Benefit	Retransmissions are reduced	Single power failure is reduced, low control overhead
Zones Information	Zones are overlapped	Static zone map required

6. COMPARISION OF PROACTIVE, REACTIVE AND HYBRID PROTOCOLS

In Table 5 [4, 12] we have differentiated MANETs protocols namely proactive, reactive and hybrid on the various parameters. Proactive is best in the situation where nodes communicating with each other on regular basis, require updated information periodically and thus routes are always available. On-demand routing comes into account where we want to reduce traffic overhead that is when routes are required they are initiated. While hybrid is best suitable for large networks and attempted to reduce rebroadcasting nodes, as they define a structure for taking routing decision. It eliminates single point failures because it allows any number of nodes to perform routing or data forwarding if the preferred path becomes unavailable.

The various ant colony based routing protocols which solve the routing issue are AntNet [25], ARA [26], AntHocNet [27], ABC [28], and PERA [29], among these we will discuss Ant Colony Based Routing Algorithm (ARA) [24, 26], AntNet [24, 25], AntHocNet [24, 27].

Table 5: Difference of Proactive, Reactive and Hybrid protocols

Parameters	Proactive	Reactive(on-demand)	Hybrid
Routing	Flat and Hierarchical	Flat	Hierarchical
Route Availability	Always route is available	Determine on-demand	It depends on location of destination.
Network Mobility	Low	High	Very high
Control Traffic	High	Low	Lower than other two types
Periodic Message	Required	Not required	Sometimes used inside each zone.
Routing Information	Stored in routing tables	Doesn’t stored	If requirement is there then provided.
Delay	Low	High	Low (in Intrazone) and High (in Interzone)
Benefit	Rapid establishment of routes & routing information is updated periodically.	Obtain required route when needed & don’t exchange routing table periodically & loop free.	Updated routing information, limited search cost & more scalable.
Drawback	Convergence time is low, resource amount is used heavily, routing information flooded in whole network.	Routes are not up-to-date, large delay, more packet dropping.	Required more resources for larger size zones.

Table 6: Year wise ant algorithms for ad hoc networks

YEAR	AUTHORS	ALGORITHM	ALGORITHM TASK
1991	Dorigo, Maniezzo, Colorni	AS	Travelling salesman
1997	Gambardella, Dorigo	HAS-SOP	Sequential ordering
1998	Di Caro et al.	AntNet	Proactive routing using single path
2002	Gunes et al.	ARA	Reactive routing using multipath
2002	Marwaha et al.	Ant-AODV	Hybrid routing using multipath
2003	Baras & Mehta	PERA	Proactive routing using single path
2004	Di Caro et al.	AntHocNet	Hybrid routing using single path
2005	Wedde et al.	BeeAdHoc	Reactive routing using broadcast approach
2007	Aissani et al.	Ant-DSR	Reactive routing using broadcast approach
2008	Wanga et al.	HOPNET	Hybrid routing using muticastpath
2009	Prasad et al.	PAR	Hybrid routing using muticastpath
2010	Sehi et al.	ANT-E	Hybrid routing using single path
2011	Okazaki et al.	AD-ZRP	Reactive routing using muticastpath

7. ACO BASED PROTOCOLS

During last year’s, ant based algorithms have captivated the researchers for solving routing problems in MANETs. MANET routing issues [23] have been resolved so far by using existing ACO based routing protocols and still enhancement in these protocols is in its progress. [3, 23and 24] Yearly development of ant algorithms for routing in MANETs is presented below in the Table6.

7.1 ARA

Gunes et al proposed Ant Colony Based Routing Algorithm (ARA) [26] which reduces overhead, because routing tables are not interchanged among nodes. It consist of three phases namely Route Discovery phase, Route Maintenance and Route Failure Handling. The Route Discovery phase consist of two mobile agents that is Forward Ant (FANT) for route request and other agent is Backward Ant (BANT) for route reply to create new routes. FANT packets have unique sequence number and source address is broadcasted by the sender and will be passing on by the neighbors of the sender. Node receiving the FANT for the first time generates a record with entries of destination address (Source address of FANT), next hop (address of previous node), and pheromone value (number of hops the FANT needed to reach this node). The destination node extracts information of FANT, destroys it and creates BANT which establish pheromone track to destination node.

In Route Maintenance phase, DUPLICATE ERROR flag is set for duplicate packets to prevent from looping problems. ARA also allows for the evaporation of pheromone by decrementing factor [24] in route table. In Route Failure Handling phase, node deactivates the path by reducing pheromone value to 0 in corresponding route table entry and go to the Route Discovery phase for selecting path and sending packets to the destination over that path [26].

7.2 AntNet

Di Caro and Marco Dorigo proposed AntNet [25] which is based on two mobile agents traverse from source to destination d, to collect information regarding congestion, delay and path in network. These agents are Forward Ant (FA) and Backward Ants (BA). Source generates FA which uses routing table Tk which stores probability value Pnd for destination-neighbor pair, to find path to destination and record the route it has taken. When they reached at the destination FA dies and creates the BA which goes back to the source by moving along the same path followed by the FA but in opposite direction. During this traversal by BA, [24] it modifies routing table by increasing the routing probability of FA and decrease in probability of all other neighbor nodes, but this increase and decrease should be done at the total of all probabilities will remain 1.

7.3 AntHocNet

AntHocNet the hybrid algorithm propose by Di Caro, Frederick Ducatelle and Luca Maria Gambardella [27]. During reactive path setup, multiple routes are set on demand by broadcasting reactive FANT and gather information of about quality of path they followed. When node receives a number of ants in case of broadcasting, then node compares the path travelled by each new ant to that of former received ants of this generation and rebroadcast only if its number of hops and travel time are both within an acceptance factor of best forward ant. Once paths are setup, source starts sending proactive FANT to destination on the basis of pheromone values combine with small probability at each node of being broadcast. Hence route path discovered so far can be improved. During link failure node sends notification to its neighbors and updates routing table to give better packet delay and delivery ratio than AODV [24, 30].

7.4 Summary

On taking diverse parameters like type of information collected by ants, amount of pheromone deposited, ants and routing table composition we can differentiate various ant based routing protocols as did below in Table 7 [24] of ARA, AntNet and AntHocNet.

Table 7: Comparison between ARA, AntNet and AntHocNet

Parameters	ARA	AntNet	AntHocNet
Routing Overhead	Less	More	More
Routing Approach (Reactive or Proactive)	Reactive	Reactive	Both
Type of Information (collected by forward ants)	Cost of link	Congestion and delay	Quality of path
Ant Composition	Source IP address, dest IP address, sequence number and hop count	Source IP address, dest IP address, sequence number and memory	Source IP address, dest IP address, sequence number and next hop IP address, stack, hop count
Routing Table Composition	Destination address, next hop and pheromone value	Destination address, neighbor node and pheromone value	Destination address, next hop and goodness of next hop
Amount of Pheromone Deposit	Nondecreasing function of link costs	Constant	Function of total cost from source to destination

8. CONCLUSION

In this paper, we are presenting brief overview to MANETs and ACO based routing protocols and recommended which protocol can be best fit in changing network scenarios. The unique characteristics of MANETs and ACO based routing protocols are reviewed. We also have given comparison on various parameters between MANETs protocols such as in proactive, reactive and hybrid and between all the three categories. As mobile ad hoc networks has a dynamic topology and limited bandwidth causes the routing issue and great overhead, so for that we entail decentralized adaptive routing strategies that cope with this issue of routing. Hence we presented various ACO ad hoc routing protocols along with comparison table. At last differentiated MANETs and ANTS to reveal the fact that although they both posses same physical structure but still possess different overhead rate and packet delivery ratio. Difference between various ad hoc routing protocols is yield in the ways of discovering routes between source and destination and maintenance of the routes. Hence these surveys will helpful researchers to choose right ad hoc routing protocol for their work according to network scenarios.

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