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Analysis and Comparison Routing Protocols based on ACO and Without ACO in MANET

Marjan Kuchaki Rafsanjani and Hossein Motahari

Department of Computer Science, Shahid Bahonar University of Kerman, Kerman, Iran
kuchaki@uk.ac.ir
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Abstract. Mobile Ad-hoc Networks (MANETs) are a set of mobile nodes which communicate without any fixed infrastructure and centralized controller. Routing in such networks is a big challenge because of the dynamic nature of this networks that each node keeps moving continuously, power energy and bandwidth are limited. Finding routes which moreover optimization, reduce the overhead of the networks. Different protocols are proposed for routing in MANETs, but nowadays researchers incorporation routing protocol with swarm intelligence (SI) techniques. One of the important techniques is, use of ant colony optimization (ACO) with routing protocols. Nature has proven that the ants finding optimal path between the nest and food and adaptive nature of this agent, make help to propose a suitable routing protocol for MANETs. In this paper, we review some routing protocol that mingle ACO with existing routing protocol and introduce the advantages and disadvantages of them. Finally, we compare these protocols to each other.

Keywords: Mobile ad-hoc networks (MANETs), Ant colony optimization (ACO), Routing

1. Introduction

Mobile Ad Hoc Networks, are dynamically configurable wireless networks without fixed infrastructure or central administrative management [1]. Each node has limited power and communicates with other node that exists within the transmission range directly otherwise communication is done through intermediate nodes [2] hence these networks are also called as multi-hop networks [3]. Any node can be a sender, a receiver as well as a router where it takes part forwarding other node's packets [4].Due to the random movement of nodes, the network topology may change continuously and unpredictably over time. Then we have to use the protocol that deals with the dynamic aspects of MANETs in their own way and own metrics[5].Mobile nodes and multi-hop nature of MANETs also poses other problems as the nodes can move freely and the network topology may change very often. To support this new communication paradigm, robust, reliable and efficient routing algorithms are needed to allow the network to offer a good, or at least an acceptable, level of service. New approaches are needed to overcome the difficulties and proposed a suitable routing protocol is still a challenge.

Basically, Routing is the process of choosing paths in a network along, so that the source can send data packets towards the destination. Routing is an important phase of network communication because the characteristics like throughput, reliability, packet delivery, congestion and so on depends upon the routing information [6].

Swarm Intelligence based Routing with Opportunistic Routing represent sets of algorithms based on biological models, inspired by highly dynamic environments, which are particularly adequate for MANETs [7].

Ant Colony Optimization (ACO) is a subset of Swarm Intelligence. It is introduced by Marco (1992) [6]. The main idea of the ant colony optimization is taken from the food searching foraging behavior of real ant colonies[8, 9]. When ants are on the way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to go. While going, ants deposit a chemical substance named pheromone, which ants are able to sense, which marks the route taken and they are attracted to the marked paths. The concentration of pheromone on a certain path is an indication of its usage. The more pheromone that is deposited on a path, the more attractive that path becomes. With time, the concentration of pheromone decreases due to volatile effects. Evaporation clears the pheromone on longer paths as well as on less interesting paths. Shortest paths are refreshed more quickly with ants, thus having the

chance of being more frequently explored. Intuitively, ants will converge towards the most efficient path due to the fact that it gets the strongest concentration of pheromone[10, 11].
Nowadays, there are many routing protocols for MANETs such as AODV [12], TORA [13], ZRP [14] and so on. But researchers try to optimize thess protocols and in this way, many protocol that combine ACO with routing protocols are proposed. Samples of this combined protocols are HOPNET [15], DAR [16] and HRAZHLS [17].

The rest of the paper is organized as follows: section 2 proposes classification of Ad Hoc Routing protocols. Section 3 reviews routing protocol without Ant Colony Optimization in MANET. Section 4 describes *Ant Colony based routing* in MANET. In section 5, we investigate analysis and comparison between routing protocol that proposed with ACO and without ACO in MANET with respect to various metrics. The conclusion is given in section 6.

2. CLASSIFICATION OF AD HOC ROUTING PROTOCOLS

Multiple routing protocols have been developed for Mobile Ad hoc Networks. MANET routing protocols depend on the mechanism and functionalities can be classified into three categories [4]:

- Proactive (Table-driven)
- Reactive (On-demand)
- Hybrid

2.1.Proactive protocols

In this category, each node in the network holds one or more routing table which stores information of next hops/subnet. All nodes keep on updating these tables periodically. The drawback of this routing causes more overhead, not used for large topology network, consumption of more Bandwidth, If the network topology changes too frequently, might be very high cost of maintaining the network, information about actual topology might even not be used if network activity is low [2]. The differences among the protocols lies in their routing table structure, number of tables, updating frequency, use of control messages and the presence of a central node [3]. These protocols forward the packets irrespective of when and how routes are desired as there is always the availability of the routes in the continuously updated routed tables [18]. The main disadvantages of table-driven routing protocols are QoS, bandwidth consumption in transmitting, routing tables and also saving the table of the routes that are not used in the future[19].

2.2.Reactive protocols

Reactive protocols are elected when we want to set up 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 [18]. Advantage of reactive protocols is less control overhead as compared to proactive protocols for Mobile Ad Hoc Networks. Thus, reactive routing protocols have better scalability than proactive routing protocols in mobile ad hoc networks [3]. The main disadvantages of the on-demand protocols are dilation when the source node trying to find a route and also excessive flooding can be led to the network clogging[20].

2.3.Hybrid protocols

Hybrid routing protocols combine the advantages of proactive and reactive routing protocols. Proactive tactic is used to discover and maintain routes to nearer nodes, while routes for far away nodes are discovered reactively. In an ad-hoc network, a hybrid routing algorithm can be implemented in a hierarchical network architecture. The performance of the network depends on the distribution of the proactive/reactive approaches for each level of the network hierarchy [3]. The hybrid routing protocols disadvantage is that the nodes have to maintain high level topological information which leads to more memory and power consumption [21].

3. SOME ROUTING PROTOCOL WITHOUT ACO IN MANET

3.1. Ad hoc On Demand Distance Vector (AODV)

The AODV is a reactive routing protocol that combines the advantages of both protocols, Dynamic Source Routing (DSR) and DSDV [22]. If a node using AODV protocol for communication, send a message to a destination node for which it does not have a valid route to, it initiates a route discovery process to locate the destination node [23].

In the route discovery process a route request message (RREQ) is broadcasted to all neighbors, which continue to broadcast the message to their neighbors [24]. The neighboring nodes in turn broadcast the packet to their neighbors and the process continues until the packet reaches the destination [25] or until a intermediate node knows a route to the destination that is new enough. To ensure loop-free and most recent route information, every node maintains two counters: sequence number and broadcast_id. The broadcast_id and the address of the source node uniquely identify a RREQ message. broadcast_id is incremented for every RREQ the source node initiates [24]. When an intermediate node receives a RREQ if it has already received a RREQ with the same broadcast_id and source address it drops the redundant RREQ and does not rebroadcast it [12]. When an intermediate node forwards the RREQ message, it records the address of the neighbor from which it received the first copy of the broadcast packet. This way, the reverse path from all nodes back to the source is being built automatically. The RREQ packet contains two sequence numbers: the source sequence number and the last destination sequence number known to the source. The source sequence number is used to maintain freshness information about the reverse route to the source while the destination sequence number specifies what actuality a route to the destination must have before it is accepted by the source [24]. A RREQ is issued with a limited TTL. If no RREP message is received within a certain time by the source node, then another RREQ is issued with a larger TTL value. If still no reply, the TTL is increased in steps, until a certain maximum value is reached [25].

When the route request broadcast reaches the destination or an intermediate node with a fresh enough route, the node responds by sending a unicast route reply packet (RREP) back to the node from which it received the RREQ. So, actually the packet is sent back reverse the path built during broadcast forwarding. A route is considered fresh enough, if the intermediate node’s route to the destination node has a destination sequence number which is equal or greater than the one contained in the RREQ packet. As the RREP is sent back to the source, every intermediate node along this path adds a forward route entry to its routing table [24]. If a node does not receive a reply then it deletes the node from its list and sends RERR to all the members in the active members in the route [26]. The forward route is set active for some time indicated by a route timer entry [24]. A routing table entry is said to be expired if not used within certain duration. These nodes in Maintaining Routes process, are notified with route error (RERR) packets when the next-hop link breaks. In the situation of link break, due to mobility node, each predecessor node, forwards the RERR to its own set of predecessors. In this way all routes, which contain the broken link, are removed [25]. After having learned about the failure, the source node may reinitiate the route discovery protocol. Optionally a mobile node may perform local connectivity maintenance by periodically broadcasting hello messages [24].

3.2. Dynamic Source Routing (DSR)

Johnson and Maltz [27] proposed a reactive multi-hop routing protocols for mobile ad-hoc networks, named DSR that carries out a source routing. The basic operations of the DSR protocol are route discovery and route maintenance. DSR uses a cache to store routes recently used. If a node wants to transmit a packet to a specific destination for which it does not have a route yet, Source floods Route Request messages (RREQ) to its neighbors. Each neighbor will flood Route Request messages, storing the path in the header, except the case, when it is itself the destination or it has a portion of route towards this destination in its cache. Itsuch a node responds with a Route Reply message (RREP) containing the path. Also a node can only flood the Route Request packet if it has not already flooded. This mechanism performed by Sequence numbers lie in the packet. Sequence numbers are used to prevent loops. The route found is stored in the cache of nodes for future transmit [28]. At each hop, the best route with minimum hop is stored [29].

When a link is broken, the route maintenance mechanism is started. Adjacent node sends a Route Error message (RERR) to the source. The source will remove the route from its route entry list and if the source also needs a route it initiates route discovery phase [28].

DSR attempt to minimize control overhead by: (a) maintaining path information for only those destinations with which the router needs to communicate, and (b) using the paths found after a flood search as long as the paths are valid, even if the paths are not optimum [30].

Some optimizations on DSR, such as follows, are proposed:

a) *Preventing RREP storms:* RREP storms occur when several nodes send RREP to the source from their caches at the same time. This produces congestion and slows down the routing. To overcome this difficulty, a random delay period is introduced on each node to control sending RREPs.

b) *Limiting RREQ hops:* The TTL field in the header of RREQ packet, allows decreasing the flooding negative effects, particularly, in larger networks.

c) *Salvaging of packet:* When a link is broken, adjacent node Instead of removing a packet, can rescue it by using an alternate route from its cache and sends a Route Error message (RERR) with alternate route to the source [31].

The protocol allows multiple routes to any destination and allows each sender to select and control the routes used in routing its packets, for example for use in load balancing or for increased robustness [22].

3.3.Zone-based Hierarchical Link State (ZHLS)

Mario et al., proposed a global positioning system (GPS) -based routing protocol for mobile ad hoc networks, called zone-based hierarchical link state (ZHLS) routing protocol, that generates less overhead than the schemes based on flooding [32]. ZHLS is a hybrid routing Protocol based on node ID and zone ID approach and mobile nodes are assumed to know their physical locations with assistance from a locating system like GPS. The network is divided into non-overlapping zones based on geographical information. ZHLS uses a hierarchical addressing scheme that contains zone ID and node ID [33].Zone naming is done at the design phase, therefore each node can determine exactly at any time its zone ID bymapping its physical position to a predefined zone map [34].

It is assumed that a virtual link connects two zones if there exists at least one physical link between the zones. A two-level network topology structure is defined in ZHLS, the node level topology and the zone level topology. Respectively, there are two kinds of link state updates, the node level LSP (Link State Packet) and the zone level LSP. A node level LSP contains the node IDs of its neighbors in the same zone and the zone IDs of all other zones.

A node periodically broadcasts its node level LSP to all other nodes within the same zone. Therefore, through periodic node level LSP exchanges, all nodes in a zone keep identical node level link state information. Whenever a virtual link is broken or created, gateway nodes broadcast the zone LSP throughout the network [33].Then all network nodes construct two routing tables, an intrazone routing table and an interzone routing table, by flooding Node LSPs within the zone and Zone LSPs throughout the network [26].Each node knows only the node connectivity within its zone and the zone connectivity with all other zones in the whole ofthe network. When a node decides to send a packet, before sending packets, a source firstly checks its intrazone routing table. If the destination is in the same zone as the source, the routing information is already there and the route is ready. Otherwise, the source sends a location request to all other zones through gateway nodes. After a gateway node of the zone, in which the destination node resides, receives the location request, it replies with a location response containing the zone ID of the destination.
The pair of zone ID and the node ID of the destination node will be specified in the header of the data packets originated from the source node. During the packet forwarding procedure, intermediate nodes except nodes in the destination zone will use interzone routing table, and when the packet arrives the destination zone, an intrazone routing table will be used for communication.

ZHLS use proactive routingfor intrazone communication and reactive routing for interzone packet forwarding. Performance of a zone based routing protocol is depended on theperformance of respective proactive and reactiverouting protocols chosen and how they cooperateeach other [33].

The advantage is no overlapping zones are here. The zone level topology information is distributed to all nodes. Reduces the traffic and avoids a single point of failure. The disadvantage is additional traffic produced by the creation and maintaining of the zonelevel topology [22].

3.4.Dynamic MANET On-demand (DYMO)

The DYMO routing protocol is proposed for use by mobile routers in wireless, multihop networks. This protocol is an on-demand routing protocol and use the unicast multipath routes among participating DYMO routers within the network [35, 36]. DYMO is based on two triggered mechanisms, namely, the route discovery and the route maintenance.

During route discovery, the source router initiates dissemination of a Route Request (RREQ) throughout the network to find a route to the destination router. During this hop-by-hop process, each intermediate DYMO router records a route to the originator (source router). The first time a DYMO router issues a RREQ, it waits RREQ_WAIT_TIME for a route to the TargetNode. If a route is not found within that time, the DYMO router may send another RREQ. If a route discovery has been attempted RREQ_TRIES times without receiving a route to the TargetNode, all data packets destined for the corresponding TargetNode are dropped from the buffer and a Destination Unreachable ICMP message should be delivered to the source. When the destination router receives the RREQ, it responds with a Route Reply (RREP) sent hop-by-hop toward the source router. Each intermediate DYMO router that receives the RREPcreates a route to the target, and then the RREP is unicast hop-by-hop toward the source. When the source router receives the RREP, routes have then been established between the source DYMO router and the target DYMO router in both directions.

Route maintenance consists of two operations. In order to preserve routes in use, when DYMO routers successfully forwarding a packet, then they extend route lifetimes. In order to react to changes in the network topology due to the mobility of the nodes or other reasons, DYMO routers monitor routers over which traffic is flowing. When a data packet is received for forwarding and a route for the Specified destination is not known or the route is broken, then the DYMO router of the source of the packet is notified. A Route Error (RERR) is destination is invalid or missing. When the source's DYMO router receives the RERR, it deletes the route. If the source's DYMO router later receives another packet for forwarding to the same destination, it will need to perform route discovery again for that destination.

DYMO uses sequence numbers that is maintained by each router to ensure loop freedom. Reactive nature makes DYMO is applicable to memory constrained devices. Each router needs to maintain a reactive routing table with seven Forced fields (Route.Address, Route.Prefix, Route.SeqNum, Route.NextHopAddress, Route.NextHopInterface, Route.Forwarding, Route.Broken). Route message contains three fields (Node.SeqNum, Node.Dist, and RM message type (RREQ/RREP)).

DYMO handles a wide variety of mobility patterns and also handles a wide variety of traffic patterns and supports routers with multiple interfaces participating in the MANET [35].

Table 1: Relative comparison of routing protocols without ACO in MANET

Algorithm	**AODV**	**DSR**	**ZHLS**	**DYMO**
Year	1999	1996	1999	2009
Routing Approach	Reactive	Reactive	Hybrid	Reactive
Topology Structure	Flat	Flat	Hierarchical	Flat
Path Type	Single path	Multipath	Multipath	Multipath
Information keep in the route table	Destination, Next Hop, Number of hops (metric), Sequence number for the destination, Active neighbors for current route, Expiration time for the route table entry	This protocol does not use routing tables since all the nodes can read the next hop in the packet header. DSR uses a cache to store routes recently used.	Depended on the performance of proactive and reactive routing protocols chosen	Route. Address, Route.Prefix, Route.SeqNum, Route.NextHop-Address, Route.NextHop-Interface, Route.Forwarding, Route.Broken
Advantages	Loop-free routes, Scales to large populations of mobile nodes, reduces control overhead, The connection setup delay is lower, Periodic beaconing leads to unnecessary bandwidth consumption, Freshness routes, tries to minimize the number of required	Guaranteed loop-free routing, Less memory storage needed at each node if a full routing table is not needed, Lower overhead needed because no periodic update message is necessary, Nodes do not need to continually inform the neighbors. They are still operational, DSR is	Generates less overhead than the schemes based on flooding, no overlapping zones, Reduces the traffic and avoids a single point of failure	DYMO is applicable to memory constrained devices. It is loop-free protocol, handles a wide variety of mobility patterns, handles a wide variety of traffic patterns, Supports routers with multiple interfaces

	broadcasts, Reduces memory requirements and needless duplications	able to adapt quickly to changes such as host movement		
Disadvantages	High route discovery latency for large network (Scalability problem) and therefore may not be applicable in real-time communication applications.	Possible transmission latency due to reactive approach, Stale routes can occur if links change frequently, Message size increases as path length increases	Additional traffic produced by the creation and maintaining of the zone level topology, needed a system location assistance such as GPS	Increases the size of the routing packets

4. ROUTING PROTOCOLS BASED ON *ANT COLONY* IN MANET

4.1. Ant-AODV

Marwaha et al. [23], proposed a routing protocol based on AODV and Ant colony optimization, named Ant On-Demand Distance Vector Routing (Ant-AODV). Each routing, the ACO or AODV independently has some disadvantages which make them not good routing approach. Ant-AODV is a hybrid protocol with the advantages of AODV and ACO, to overcome some of their inherent drawbacks [23]. AODV is the reactive part of it and ant-based approach is the proactive part of it. The main goal of the ant algorithm here is to continuously create routes in the attempt to reduce the end-to-end delay and the network latency, increasing the probability of finding routes more quickly, when required while offering a better connectivity [31, 37]. But produce more overhead than AODV. This protocol uses ant agents that work independently and provide routes. The use of ants with AODV increases the node connectivity, which decrease the amount of route discoveries [23]. A fixed number of ants keep going around the network in a more or less random manner, proactively updating the AODV routing tables in the nodes they visit whenever possible[38].Each node via sending periodic HELLO messages to its neighbors, maintain a neighbor tableWhich is used for selecting the next hop by the ants. Ant-AODV uses RREQ messages for establishing a new route and also uses RERR messages to inform upstream nodes of a local link failure. Ant-AODV improved end-to-end delay, connectivity (more than double) and route discovery latency than AODV [23].

4.2. Ant-DSR (ADSR)

Aissani et al. [31], proposed a novel routing algorithm for mobile ad-hoc networks named ANT-DSR that combine features of ACO with DSR protocol. Ant Dynamic Source Routing (Ant-DSR) is a reactive protocol, which Unlike DSR, Ant-DSR brings back refreshed routes by the ant-agents. This protocol uses a distributed topology discovery mechanism through mobile agents to maintain DSR cache. In fact, unicast movement of ant agents is only possible by the maintenance of a neighborhood table updated as well as the cache of each node. Moreover, this table is not updated by a Sacred mechanism; information about neighbors is available on any packet received at a node. One year later Asokan et al. [11], proposed a new approach of ADSR with different kinds of ant agents. Mobile nodes are required to maintain route caches that contain the source routes, of which the mobile is aware. Entries in the route cache are continually updated as new routes are found. In this protocol, ADSR divided intotwo basic phases: route discovery and route maintenance.

When a mobile node (source node) wants to send a packet to a special destination, at the first it looks at its route cash to determine whether it previously has a route to the destination. If it has an unexpired route to the destination, it will use this route to send the packet. Otherwise, if the node does not have such a route, it initiates route discovery by broadcasting a route request packet (RREQ). This route request contains the address of the destination, along with the source node's address and a unique identification number (RREQ ID). Each node receiving the packet checks whether it knows of a route to the destination. If it does not, it adds its own address to the route record of the packet and then forwards the packet again. For premonition of the loop, a mobile node only forwards the route request if the request has not yet been seen by the mobile and if the mobile's address does not already appear in the route record. A route reply (RREP) is generated when the route request either reaches the destination itself, or reaches an intermediate node which contains in its route cache an unexpired route to the destination. Route reply packet will send to the source and intermediate nodes update route cash by receiving a RREP. Route maintenance is accomplished through the use of route error packets and acknowledgments.

In Ant-DSR (ADSR) the Forward ant (FANT) and backward ant (BANT) packets are added in the route request and route reply of DSR respectively. FANT and BANT packets are used in this route discovery process. FANTs are used to explore new paths in the network [11]. Ants measure the current network state, for instance by trip times, hop count or Euclidean distance travelled. Backward ants serve the purpose of informing the originating node about the information collected by the forward ant.

ADSR increases the probability of a given cached route express the network reality [4].

4.3. HRAZHLS

HRAZHLS is a hybrid routing algorithm that has the potential to provide higher scalability than pure reactive or proactive protocols. This protocol consists of the proactive routing within a zone and reactive routing between the zones. The network is divided into zones which are the node's local neighborhood. The network is divided into non-overlapping zones; a node is only within a zone [17]. Given the zone id and the node id of a destination, the packet is routed based on the zone id till it reaches the correct zone. Then in that zone, it is routed based on node id. A <zone id, node id> of the destination is sufficient for routing so it is adaptable to change topologies [17, 32]. The zone size depends on node mobility, network density, transmission power and propagation characteristics. Each node knows its physical location by Geo-location techniques such as Global Positioning System (GPS). The nodes can be categorized as interior, exterior and gateway nodes. Each node only knows the connectivity within its zone and the zone connectivity of the whole network.

The algorithm has two routing tables, Intrazone Routing Table (IntraRT) and Interzone Routing Table (InterRT). IntraRT is maintained proactively. A node can determine a path to any node within its zone immediately. InterRT is a routing table for storing routes to a destination out of its zone. The gateway nodes of the zone are used to find routes between zones.

This algorithm uses five types of ants: internal forward ant, external forward ant, backward ant, notification ant and error ant. The internal forward ant is the responsible for maintaining the proactive routing table continuously within its zone. The external forward ant performs the reactive routing to nodes beyond its zone. In route discovery within a zone (Intrazone routing), each node periodically sends internal forward ants to its neighbors to maintain the intrazone routing table updated. When a node wants to transmit a data packet to the destination node within its zone, it first searches at the IntraRT table to see if the destination exists in its zone. If it finds the destination in its IntraRT, then route discovery phase is done. After selecting a node as next hop increase pheromone concentration selected link and along all other links the pheromone is decremented. If not found the destination in its IntraRT, then Route discovery between zones is done. In route discovery between zones (Interzone routing), When a node wants to send a data packet to a destination node, it verifies the Interzone routing table to discover an existing route. If the route exists and has not expired, then the node transmits the data packet. Otherwise, the node starts a search process to find a new path to destination. When a source node will transmit a data packet to a node thither its zone, the node sends external forward ants to search a path to the destination.

The external forward ants are first sent by the node to its gateway nodes. The gateway nodes check to see if the destination is within its zone. If the destination is not within its zone and the path has expired, the ants jump between the border zones via the order gateway nodes until an ant localize a zone with the destination. This ant propagation through the border zones is called bordercast. At the destination, forward ant is converted to a backward ant and is sent to the source. Then, the data packet is transmitted. Use bordercast and routing table process reduces the delay, because IntraRT proactively maintains all the routes within its zone and InterRT stores the path to the destination that the ants recently visited [17]. Damaged route cause an intermediate node will not be able to deliver packets. If the damaged route is within a zone, it will recover after a period because the IntraRT is proactively maintained. If the damaged route is between zones, the up node of the broken link will conduct a local repair process and then search an alternative path to the destination while buffering all the packets it receives. If the node finds a new path to the destination, it will send all the buffered packets to the destination; then a notification ant will be sent to the source to allow the source node knows the change of route. If a new path cannot be found instead failed path, an error ant will be sent to the source node. Hence packet delivery ratio will be increased [15].

The pheromone value gets updated by the ants as they move the links. The ants change the concentration of the pheromone value on their path to the destination and on their route back to the source[17].

4.4. Ant-DYMO

Ant-DYMO is a hybrid and multi hop protocol that uses an ant based approach in its proactive phase while DYMO is the basis for the reactive one. This protocol uses two types of ants, named explorer ant (EANT) and search ant (ARREQ).EANTs are the same as BANTs in other protocols and they are responsible for creating routes to the source node. The EANTs carry the address of the source node and also a list containing every intermediate node, it has passed by [37].ARREQs are the same as FANTs and RREQs in other algorithms. The main goal of theseants is searching for a specific destination. [39]

Nodes acquire their neighborhood information by the limited flooding of Hello messages and based on receiving responses to this message, each node creates its routing probability table, similar ACO's pheromone table. At the first each node will broadcast EANT to its neighbors. At first step receiver node check the EANT.Here, the essential information is mostly taken from thereceived EANT.After adding the entry, the EANT is then broadcasted to thenode's neighbors.When a node S wants to send packets to a destination Dnot present in its routing table, it creates an ARREQ withits address and broadcasts it to its neighbors. In the receiver node, if it is duplicated, processed as DYMO's duplicated RREQs and discarded. Otherwise in a second step if the node is the destination, its create RREP message and send back to the source. If the node is not destination check its routing table and if the destination is onthe routing table, the node selects a route probabilistically based on its routing/pheromone table. Then node creates a RREP message and transmit back to the source. In the case that destination is not in the routing table of the node, the node adds its address to the ARREQ's route record and adds an entry in its routing table. ARREQ's hop count incremented by one. Node forwards this ARREQto its neighbors. In this protocol there isn't any special packet for route maintenance due to two reasons:

- The EANTs keep providing routes all the time, increasing the probabilities of quickly finding an alternate path in case of route errors.
- The data packets– mimicking the behavior of real ants– will enforce the pheromone trail of the selected path [37]. This mechanism is similar to ARA [40].

Table 2: Relative comparison of *Ant Colony routing protocols* in MANET

Algorithm	**Ant-AODV**	**Ant-DSR**	**HRAZHLS**	**Ant-DYMO**
Year	2002	2007	2010	2010
Routing approach	Hybrid	Reactive	Hybrid	Hybrid
Types of Ants	Ant agents	Forward ant (FANT), Backward ant (BANT)	Internal forward ant, external forward ant, backward ant, notification ant, error ant	Explorer ant (EANT) Search ant (ARREQ)
Pheromone enforcement	Ant agents	BANTs	All five types of ants	Explorer ant (EANT) and data packet
Topology structure	Flat	Flat	Hierarchical	Flat
Path Type	Single path	Multipath	Multipath	Multipath
Types of nodes	Simple nodes	Simple nodes	Interior nodes, exterior nodes, gateway nodes	Simple nodes
Information that each node keep in table	Destination node address, number of hops to reach that destination, the next hop to route the packets, the sequence number of the destination and the time to live for that route.	Nodes using routing cash just like as DSR	Connectivity within its zone and the zone connectivity of the whole network that each link in the table contains pheromone value and the time which the links may be in connection	Destination (the node that generated the EANT), next hop (the last node visited by the EANT, taken from its list of hops), pheromone level (the amount of pheromone over the link e (current node; destination))
Acquire	Ants keep a history of	IP header, DSR	Route information	IP.SourceAddress

information with ant	the nodes previously visited by them	fixed header, Source address, Sequence number, Destination number, Delay energy jitter, Route record, Hop count, Route address (Add1, Add2,…, Addn)	such as node id and zone id of intermediate nodes	IP.DestinationAddress UDP.DestinationPort MsgHdr.HopLimit AddBlk.OrigNode.Address OrigNode.AddTLV. SeqNum
Advantages	To reduce the end-to-end delay and route discovery latency, providing high connectivity, route discoveries are reduced, suitable for real time data and multimedia communication	Loop free, propose refreshed routes, Suitable for network with high mobility and a huge network	Highly scalable, low end-to-end delay, High packet delivery ratio	Low end-to-end delay, high packet delivery ratio, delivered the data in less time
Disadvantages	More overhead as compared to AODV, Route Error	Extra control packets are required periodically to monitor the condition of the paths	Needed a system location assistance such as GPS, periodical control packets that make overhead within the zone	Extra overhead

5. DISCUSSION ON ROUTING PROTOCOLS BASED ON ACO AND WITHOUT ACO IN MANETS

5.1. AODV Versus Ant-AODV

AODV is a reactive routing protocol. If we added ant-based approach to this reactive part, we can obtain Ant-AODV as a hybrid routing protocol [39]. Ant-AODV overcomes the inherent shortcoming of the AODV and improved parameters such as end-to-end delay, route discovery latency, node connectivity [6]. AODV has long delay before the actual connection is established and may not be applicable in real time communication applications. Using ACO in Ant-AODV make high connections and produce a suitable protocol for real time data. This high connectivity in Ant-AODV is more than double the connectivity in AODV. High connectivity leads to lesser route discoveries and reduced end-to-end delay.

Normalized overhead in AODV is the least. This factor is slightly greater in Ant-AODV as compared to AODV because of the continuous movement of ants in the network [23].

Table 3: Comparison AODV with Ant-AODV

Parameters	**AODV**	**Ant-AODV**
Routing type	Reactive	Hybrid
Routing overhead	Low	High
End-to-End delay	High	Low
Route discovery latency	High	Low
Connectivity	Low	High
Suitable for real time data	No	Yes

5.2. DSR versus Ant-DSR

Table 5 presents, compares between DSR and Ant-DSR. As you can see Ant-DSR shows a better resistance in high mobility and huge load environments in comparing DSR. Also Ant-DSR has better performance in term of end-to-end delay and loss ratio. In Ant-DSR unlike DSR, the cache is refreshed permanently, and thus the diffusion of RREQs is limited. Indeed Ant-DSR surpasses DSR into account number of RREQs. The average delayin Ant-DSR is lower than DSR. At the version of Ant-DSR that proposed by Aissani et al. [31]had claimed that in term of loss ratio Ant-DSR achieve better results. Consequently, overhead is decreased. But in the other version of Ant-DSR (ADSR) that proposed with Asokan et al. [11] with changing kinds of ant, have claimed that overhead in Ant-DSR is higher than DSR. Also energy, jitter, throughput is lower in DSR[4, 39].

Table 4: Comparison DSR with Ant-DSR

Parameters	**DSR**	**Ant-DSR**
Routing type	Reactive	Reactive
Routing overhead	High	Low
End-to-End delay	High	Low
Energy balance	Low	High
Delay Jitter	High	Low
Average delay	High	Low
For network with high mobility	Bad	Good
Loss rate	High	Low
Load balancing	Low	High
Packet Delivery Fraction	High	Low
Throughput	Low	High
Diffusion of RREQ	High	Low
Residual energy	Low	High

5.3. ZHLS versus HRAZHLS

HRAZHLS has better performance as compared ZHLS. HRAZHLS due to using ACO in its structure therefore has a lower delay. The packet delivery ratio is greater in HRAZHLS also overhead has been improved in this protocol as mentioned in the below table.

Table 5: Comparison ZHLS with HRAZHLS

Parameters	**ZHLS**	**HRAZHLS**
Delay	High	Low
Packet delivery ratio	Low	High
Overhead	High	Low

5.4. DYMO versus Ant-DYMO

DYMO is a reactive protocol. With increase ACO as a proactive phase to DYMO, we can obtain hybrid routing protocol named Ant-DYMO. In table 3 we show that Ant-DYMO has improved packet delivery ratio and the end-to-end delay rather than DYMO. Therefore Ant-DYMO protocol takes less time, in average, to deliver its packets. Also, this protocol performs better than DYMO in a network with more mobility.

When the network has less nodes, the lost rate in Ant-DYMO is nearly the same observed with DYMO. However, when the number of nodes is larger, the loss rate increase in most cases. This event is due to a large number of ants and the extra overhead, they add to the network. The most vulnerable point of the Ant-DYMO protocol is routing overhead. There are two main reasons for this increased overhead, the extra traffic generated directly by the EANTs and retransmissions created indirectly by the cashing mechanism that may provide outdated or in existing paths. Ant-DYMO had in average a routing overhead of about 15% greater than DYMO [37].

Table 6: Comparison DYMO with Ant-DYMO

Parameters	**DYMO**	**Ant-DYMO**
Routing type	Reactive	Hybrid
Routing overhead	Low	Medium
End-to-End delay	High	Low
Packet delivery ratio	Low	High
For network with more mobility	Good	Better
Loss rate	Low	Medium

6. Conclusions

In this paper, we have compared between application of routing algorithm based ant colony optimization and application of routing algorithm without ant colony optimization to solve the routing problem in MANETs. This work aims to provide a view for researchers worldwide to get an overview of the proposed routing protocols. To know about their characteristics, performance, advantages and disadvantages. We have compared some various ACO based algorithms to the original ones and results show that the protocols which use ACO have more efficiency for routing in MANETs. In future a more critical performance evaluation of ZHLS protocol rather than HRAZHLS shall be done on the basis of simulations and varying performance metrics.

7. References

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