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ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORK BASED ON SWARM INTELLIGENCE

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Abstract: Mobile Ad Hoc Networks are communication networks built up of a collection of mobile devices which can communicate through wireless connections. The nodes communicate through wireless network and there is no central control. Routing is the task of directing data packets from a source node to a given destination. This task is particularly complex due to the dynamic topology, limited process and storing capability, bandwidth constraints and lack of the central control. Suitable routing protocols are required that are robust, reliable, efficient and at the same time as simple as possible. There exist a number of swarm intelligence based protocols that try to meet these criteria. They are based on the behaviour of animals that form swarms. Two popular group of such protocols are bee- and ant-inspired protocols, which take their principles from ant and bee colonies. In this paper the principles of SI, the features, advantages and Disadvantages of the protocols based on SI are compared with each other and the non-swarm intelligent protocol AODV.
Keywords – MANET, Swarm Intelligence, AdHoc, ARA, AntHocNet, HOPNET.

I. INTRODUCTION

Swarm intelligence is the discipline that deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization. In particular, the discipline focuses on the collective behaviours that result from the local interactions of the individuals with each other and with their environment. Examples of systems studied by swarm intelligence are colonies of ants and termites, schools of fish, flocks of birds, herds of land animals etc. The nature of swarms largely resembles mobile ad-hoc networks (MANETs) and that is why ideas from swarm animals like ants and bees are used for creating suitable routing protocols for MANETs.

The basic idea behind ant-based routing algorithm is taken from the food searching strategy of real ants. They start searching food from their nest and walk towards the food, sampling different routes. When an ant reaches an intersection it has to make a decision which way to take next. Also while walking (to the food source and back), ants leave pheromone, a chemical substance, which marks the route they took. Other ants can smell the pheromone. They can distinguish its concentration as well, which gives a hint to them for the usage of the route and influences their choice. With time the concentration of pheromone decreases due to diffusion. This property is important for knowing which route is becoming less occupied, probably due to some deterioration.

Bee-inspired algorithms are mainly based on the foraging principle of honey bees. Two main types of bees are utilized for doing routing in MANET - scouts and foragers. Scouts discover new nodes from their source node to their destination node. When a scout reaches its destination, it starts a backward

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journey to its source. When returned to the source, a scout recruits the foragers for its route by using the metaphor of dance.

Principles of Swarm Intelligence:

1. Diversity: Giving differences is a vital component of swarm knowledge. It enhances the framework's capacity to respond to unforeseen and obscure circumstances.
2. Adaptability: Swarming makes the framework versatile to an ecological or geological changes. It makes the framework adaptable.
3. Proximity : implies closeness. It keeps the framework clients close or mindful of the framework, foundation subtle elements, framework changes and disappointment.
4. Stability: It makes the framework steady. It gives atomicity. Framework works in a similar manner and gives comparative reactions to every single ecological vacillation making it stage free
5. Quality: Framework ought to give expected and remedy yields with no or unimportant errors.
6. Stigmergy : It is a mechanism that provides self-organization and forms indirect coordination between agents and their neighbouring

II.ANT BASED ROUTING PROTOCOLS

The first protocol taken into account in this work is

- AntColony-Based Routing Algorithm (ARA). It is a highly adaptive, scalable efficient on-demand (reactive) MANET routing protocol.
- Simple Ant Routing Algorithm (SARA) : The next algorithm considered in this work is SARA proposed by F. Correia and T. Vazao which is a kind of evolution of the one above - ARA. It offers low overhead facilitated through all three routing phases - discovery, maintenance and recovery (which will be explained later in this work). This is done by means of three complementary mechanisms - Controlled Neighbour Broadcast (CNB), maintaining active sessions paths and deep search procedure that restricts the number of nodes searched.
- A unicast protocol for hybrid ad hoc networks - ANSI (Ad hoc Networking with Swarm Intelligence) considers the existence of higher-capability mobile or stationary devices in a network. It is responsive to fluctuating topology and utilizes the common swarm intelligence routing strategies.
- Another proposal for ant-based protocol using hybrid routing is the AntHocNet It has reactive and proactive components.
- Final ant-based solution considered here is the HOPNET, which is again a hybrid protocol. It is based on ant colony optimization (ACO) and zone routing framework for broadcasting. HOPNET is highly scalable for large networks.

III.BEE BASED ROUTING PROTOCOLS

Bee-inspired routing protocols The bee-inspired protocol BeeAdHoc focuses on energy efficiency. It is a reactive source routing algorithm which strives to achieve performance similar to established MANET protocols - DSR, AODV and DSDV but on the cost of significantly less energy.

IV.COMPARISON CONDITIONS

A.Types of Network :

There are three distinctive types of network that are taken into account in this work: proactive, reactive, hybrid. In proactive protocols nodes in the network maintain routing information to all other nodes in the network by exchanging periodically routing information. Nodes with reactive protocols delay the route acquisition until there is a demand for a route. Hybrid protocols use a combination of both proactive and reactive strategies to gather routes to the destinations in a network. There can be different level of proactive and reactive routing involved, e.g. a node can collect proactively information for favourite destination nodes or nodes from the own area and use reactive routing for other nodes.

B.Phases :

i) Route Discovery Phase :

In this phase new routes are searched and established.

In the case of ARA [2], the creation of new routes requires the use of forward ant (FANT) and backward ant (BANT). A FANT agent establishes the pheromone track to the source node, while a BANT establishes the pheromone track to the destination node. The FANT is a small packet baring unique sequence number. A forward ant is broadcasted by the source node s and is relayed by the neighbour nodes. A node that receives a FANT for the first time creates a record in its routing table, consisting of destination address, next hop, pheromone value. The pheromone value is computed based on the number of hops the FANT needed to reach the node. Then the node relays the FANT to its neighbours. Duplicate FANTs are identified through the unique sequence number and source address and are destroyed by the nodes. When those FANT achieves the end hub d, its majority of the data is concentrated and the FANT will be destroyed itself. Hence d creates a BANT and sends it to the source s. The BANT has the same task as the FANT, i.e. establishing a track to s.Once BANT is received by the source node from the destination,there is establishment of path and data pckets can be sent.

By AntHocNet [5] a source node s checks its routing information if it has up-to-date route with the destination node and if not it sends a reactive forward ant similar to the ARA . The forward ant is relayed by other nodes, which initialize their routing table and the pheromone values. [2]. These ants gather information concerning the quality of the path they followed and then when they reach the destination they become backward ants which trace back their path and update routing tables. The routing tables contain information on the goodness of the paths to each destination through each next hop. This is the pheromone. With its help multiple paths between s and d can be indicated, and packets can be routed as datagrams. The choice of the path happens stochastically - in each node the packets select the next hop with a probability proportional to the pheromone values.

AntHocNet provides better ways to select which FANTS to be propagated and which to be discarded than ARA. Not only number of hops are considered, but time to reach each hop is also considered.By discarding some worse FANTS overhead is limited. By the route discovery phase SARA brings innovative approach compared to for example AntHocNet. Usually, as was seen above, the source node starts the route discovery process by sending a forward ANT, which is replicated by all network nodes until it reaches the destination node or neighbourhood. Upon receiving the first FANT, the destination sends a BANT through the shortest known path(s). If the packet arrives at the source then path is established and data flow may start. This approach requires two-way routing as with AntHocNet and creates significant amount of control information in case of long paths. The FANT is also replicated, creating flooding, which deteriorates performance.

To cope with this SARA introduces a more efficient mechanism to disseminate FANTs: Controlled Neighbour Broadcast (CNB). Here each node broadcasts the FANT to all of its neighbours, who process it, but only one of them broadcasts the FANT again to its own neighbourhood. The selection of the node responsible for "re-broadcasting" the FANT is done in a probabilistic manner.

The route discovery phase within a zone is accomplished with the help of the intrazone routing table - IntraRT, which was mentioned earlier, and internal forward ants, which are different than the external forward ants. The internal forward ants are sent periodically to all neighbours to maintain the IntraRT. In the IntraRT there is information on the neighbour nodes in a zone - pheromone, visited times, hops, SeqNo. Pheromone is for the pheromone concentration of a link, visited times gives the number of times a link has been visited by the ants, hops is the number of hops between a nodes and another node in its zone. The format of the ants contains Source, Destination, SequenceNo, Type, Hops and Path. The sequence number which is present also in the IntraRT table is for distinguishing packets and avoid duplications. The Source field stores the source address. The Destination stores the destination address, which is left blank for internal forward ants and stores the destination node's address only for external ants. The Type field indicates one of five possible ant types: internal forward ant, external forward ant, backward ant, notification ant, error ant. The Hop Field indicates the number of hops an ant can take to move forward. This field is assigned only for internal forward ants and is left blank for external. Path field represents the sequence of nodes between source and destination [6]. s first checks the columns of its IntraRT table if the destination lies in its zone, when a source node s has to send data to a destination node d. If this is the case then route discovery is done. If d is within the zone of s there will always be a route between the nodes, which is proactively maintained with periodically send ants. In the case when the source node s fails to find its destination within its zone, the InterRT table is used, which is responsible for the between zones route discovery phase. The InterRT contains paths to destinations with expiration time and sequence number (to avoid duplications). When a route outside a source's zone is searched it is checked in the table if this route has not been already discovered recently (before the expiration time), if this is the case, the source node sends its packet along the path that is pointed in the InterRT table. Otherwise external forward ants have to be sent. It is forwarded to peripheral nodes (which are known in the IntraRT table), and then possibly to other zones' peripheral nodes until the destination's node is reached. Then the external forward ant transforms into a backward ant and functions similarly to the backward ants of the other ant-based protocols seen here. When the backward ant reaches its source, the path found by it is added to the InterRT table and communication between the source and destination may take place.

ANSI has similar to HOPNET local proactive management and non-local reactive management. Its phases are not clearly described by its authors so its phases description will be skipped. The route discovery is done by the scout bees [1] in BeeAdHoc protocol. They are similar to FANTs and BANTs. As was explained above, a scout is broadcasted to all neighbour nodes with an expanding time to live timer (TTL), which controls the number of time the scout could be re-broadcasted. It starts to trace back its route to the source, when it reaches the destination. One difference with ant-based algorithms though is that when a scout is at the source node, it recruits the foragers for its route by using the metaphor of dance, just like scout bees in nature.

ii) Routing Maintenance Phase:

By the route maintenance in most cases the ant-inspired protocols use the metaphor of pheromone. The most used links experience the highest pheromone levels, while the unused ones have the lowest levels. This happens with two complementary mechanisms of increasing and decreasing the pheromone intensity. The first happens with every packet that crosses a link, reaches its destination and then produces a backward link. The decreasing happens with time when no traffic happens through nodes. By this phase ARA utilizes fully the pheromone tracks established by FANTs and BANTs and updated by transported data packets. The protocol doesn't create special extra packets for route maintenance, the only improvement to the basic principle it adds is the duplicate packets elimination based on sequence numbering and source address. The routing maintenance phase of HOPNET [6], as described by its authors, corresponds rather to the route recovery (repair) phase as defined below in this work. For the route maintenance (as considered in this current section) HOPNET makes use of pheromone concentration like the other protocols presented. The pheromone values are updated as packets traverse from source to current node, which influences ants coming subsequently from the source. Because of this, the mechanism is described with the term source update algorithm [6].

AntHocNet - When the paths are established and a data session is running, s starts to send proactive forward ants to d. These ants follow the pheromone values and the used paths are monitored. They also have a small probability of being broadcasted, so they can find new paths. The improvement that SARA brings in the route maintenance phase is in the case of asymmetric traffic (like UDP). Such traffic does not generate backward packets, which prevents maintaining correct pheromone levels. While AntHocNet solves this problem by generating additional control traffic, SARA uses special FANT messages calls super FANTs. The super FANT is generated at an end node (source or destination) where asymmetric traffic is detected. It has a pheromone reinforce equivalent capability of n standard FANTs. This super FANT is generated with lower frequency, than the arriving packet rate, which reduces overhead.

Route maintenance by BeeAdHoc is executed partly by forager bees and partly by swarm bees, as far as their definitions are given. The foragers collect state information about the network depending on their type (delay foragers and lifetime foragers) and also bring optimizations (less control overhead). The swarms help in the case where no or scarce acknowledgement are sent by destination nodes.

iii) Route Recovery phase:

The route recovery is a process that is initiated when there is detection of broken link between two nodes. The broken link may happen for several reasons, like a node 4 being turned off, failure in radio coverage or congestion that causes a higher number of collisions, etc. In MANET, these kinds of situations may occur frequently and thus, the route recovery procedure must be quickly executed with low overhead. ARA detects route failure if there is a missing acknowledgement [2]. The link is deactivated if a node gets a route error message for a link and sets the pheromone value to 0.Then an alternative link is searched in the routing table. It sends the packet vie this path if another option is found. If not the node informs its neighbours to check if they can communicate the packets. Either they can or the backtracking continues to the source node.To recover the route, AntHocNet and SARA will try to find alternative routes in the neighbourhood of the broken link. However, AntHocNet will attempt to reach the destination node with a standard FANT, but with a limited number of allowed broadcast transmissions, so that the ant is confined in the area of the destination. SARA also uses broadcast transmission with RFANT messages, but will attempt to find an alternative path that can reach the other side of the broken link instead of reach the destination node. If several nodes go down simultaneously it might not be possible to find an alternative route, using this local repair procedure. An error message is sent to the source node and the route discovery procedure is initiated,if the local repair procedure fails to succeed.

As noted in the prior section, HOPNET's route recovery, as considered here, is described in the section "Route maintenance" [6] by its authors. If there is an invalid route within a zone it is periodically repaired proactively, because of the IntraRT table which is proactively maintained. If the route is between zones, the upstream node of the broken link will try a local repair procedure, aiming to find an alternative path to the destination, while buffering the incoming packets. If the node is successful in finding alternative path, it sends a notification ant to the source that lets it know of the route change. The inner routing tables are changed and invalid nodes are also removed by all nodes on the path and initiates a new route discovery procedure. With its mechanisms HOPNET If this can nothappen, an error ant is sent to the source, which provides evolution of the methods adopted in ARA and AntHocNet presented before.

Table -1 Comparison Table based on Network type and Topology.

Table 1 shows the comparison between the routing protocols for MANET based the network type and toplogies.

Protocols	Network Type	Topology
ARA	ARA and SARA are on-demand routing protocols or in other words reactive.	The ARA algorithm supports dynamic topology with multihop paths between nodes. Its optimization method is based on individual ants and local information from them. No routing information in tables has to be transmitted to neighbours or the whole network.

SARA	ARA and SARA are on-demand routing protocols or in other words reactive.	The SARA topology is again dynamic. When it is formed only the shortest routes (with the minimum hop count) from all the broadcasted routes are stored by the network nodes.
ANSI	The pure mobile nodes in ANSI use only reactive routing and choose routes deterministically, while more capable (immobile) nodes, part of network infrastructure use a combination of both proactive and reactive routing and perform stochastic (random) routing when multiple paths are available.	The topologies supported by ANSI and AntHoc can be constantly changing as well.
AntHocNet	AntHocNet is reactive in the route discovery phase and in case of route failure. For the route maintenance phase it acts proactively.	The topologies supported by ANSI and AntHoc can be constantly changing as well.
HOPNET	The HOPNET algorithm [6] comprises two strategies - the local proactive route discovery within a node's neighbourhood and reactive communication between the neighbourhoods. So it can be derived it is a hybrid protocol. There are two types of routing tables maintained by HOPNET - Intrazone Routing Table (IntraRT) and Interzone Routing Table (InterRT).	The HOPNET network is divided into zones which are nodes' local neighbourhoods. The size of the zone is determined by the number of hops and not locally by the radius length from a node. Therefore, a routing zone consists of the nodes and all other nodes within the specified radius length. A node may be within multiple overlapping zones and zones could vary in size. The nodes can be categorized as interior and boundary (or peripheral) nodes. The distance between the boundary nodes and the central node is the specified radius. All other nodes less than the radius are interior nodes
BeeAdHoc	BeeAdHoc is reactive	BeeAdHoc is inspired the foraging principle of a honey bee colony [1]. Its Bee Agent Model consists of four types of agents: packers, scouts, foragers, and swarms

Table -2 Comparison Table for AntNet,ARA, AntHocNet and Ant AODV based on other criteria.

Routing Protocol	AntNet	ARA	AntHocNet	ANT AODV
Scheme	Proactive	Reactive	Hybrid	Hybrid
Route discovery approach	Flooding	Flooding	Flooding	Flooding
Strategy for loop prevention	Use of unique sequence numbers	Unique sequence numbers	Sequence numbers	Sequence numbers
Type of ants in use	Forward and backward ants	Forward and backward ants	Proactive and reactive forward and backward	Forward and backward ants

			ants	
Energy aware mechanism	Not available	Not available	Not available	Not available
Pheromone evaporation	Yes	Yes	Yes	Yes
Technique for detecting route failure	Not available	Backtracking	Local repair error message	Local repair error message
Type of route created	Single path	Multi-path	Multi-path	Single path
Algorithm Problem	Huge delay in propagating information	No built-in mechanism to adapt to changes in network topology	Overhead problem	Overhead in route error and repair

IV.CONCLUSION

A number of state of the art swarm-intelligence inspired MANET protocols are considered in this work and put to comparison with some criteria. It is shown that simple behavior in nature by the ants and bees, optimization and innovations in routing protocols can be done, that help outperform the standard MANET routing protocols like AODV, DSDV, DSR. Depending on application needs the presented protocols provide also customizing and tuning capabilities that can make them suitable for a wide range of MANET applications.

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