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Multicast Routing for Mobile Ad-Hoc Networks using Swarm Intelligence

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Abstract - ***An ad hoc network is a multi-hop wireless network formed by a collection of mobile nodes without the intervention of fixed infrastructure. Multicasting is an efficient way of providing services for group oriented applications. Multicasting involves transmission of packets to a group of nodes identified by a single destination address.***

Swarm intelligence refers to complex behaviors that arise from very simple individual behaviors and interactions, which is often observed in nature, especially among social insects such as ants. Although each individual (an ant) has little intelligence and simply follows basic rules using local information obtained from the environment, such as ant's pheromone trail laying and following behavior, globally optimized behaviors, such as finding a shortest path, emerge when they work collectively as a group.

Our proposed work is multicasting with multiple cores by adopting swarm intelligence. Swarm intelligence is used to select multiple cores. These multiple cores used to connect to all group members. Proposed work is designed to support group communication applications. That requires a large degree of coordination and exhibit highly dynamic group membership changes.

The proposed work is simulated using C language to test operation effectiveness in term of performance parameters such as Packet delivery ratio, Latency and route discovery time.

Index Terms- **adhoc network, Swarm Intelligence, Multicores.**

I. INTRODUCTION

Mobile wireless ad-hoc networks consist of mobile nodes that autonomously establish connectivity via multi-hop wire-less communications. Without relying on any existing reconfigured network infrastructure or centralized control, they are useful in many situations where impromptu communication facilities are required, such as battlefield communications and disaster relief missions.

Regardless of the attractive applications, the features of MANET introduce several challenges that must be studied carefully before a wide commercial deployment can be expected [1]. These include:

Routing: Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multicast routing is another challenge because the multicast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication.

Multicast communication is a very useful and efficient means of supporting group-oriented applications, where the need for one-to-many data dissemination is quite frequent in critical situations such as disaster recovery or battlefield scenarios. Instead of sending data via multiple unicasts, multicasting reduces the communication costs by minimizing the link bandwidth consumption and delivery delay. This is especially important in the context of mobile, wireless environments where bandwidth is scarce and hosts have limited power the dynamics of ad-hoc wireless networks as a consequence of host mobility and disconnection of mobile hosts pose a number of problems in designing even unicast routing schemes for effective communication between any source and destination [2].The conventional routing protocols that require to know the topology of the entire network is not suitable in such a highly dynamic environment, since the topology update information needs to be propagated frequently throughout the network . On the other hand, a demand based route discovery procedure generates large volume of control traffic. In a highly mobile environment with a large number of nodes, even if a route is discovered, a route rediscovery needs to be initiated when an intermediate node, participating in a communication between two nodes, moves out of range suddenly or switches itself off in between message transfer.

Many multicast protocols have been proposed for MANETs. Some protocols are based on constructing a tree spanning all the group members, where a node accepts packets only when they come from another node with which a tree branch has been established. However, since there is only a single path between a pair of sender and receiver, the scheme is vulnerable to network dynamics. Consequently, several protocols aim to construct a mesh that allows data packets to be transmitted over more than one path from a sender to a receiver to increase robustness at the price of redundancy in data transmission. Multicast protocols can also be classified by how multicast connectivity is established and maintained. In a source-based approach, a tree or a mesh is constructed per multicast sender where the construction process is often initiated by the sender, while in a group-shared tree / mesh approach, a single multicast connection is shared by all senders of the same group. One common technique used in this approach is to assign a node, known as the rendezvous point or the core [3], to accept join requests from members. The multicast connection then consists of shortest paths from the core to each of the members.

This paper proposes a multicast routing scheme in MANETs by using swarm intelligence. Swarm based on ant metaphor is used to select the multiple cores and also find the path between the cores in mobile ad hoc networks (MANETs). The cores are the mobile nodes that connect the group member mobile nodes in a MANET to enable reliable and faster communication.

Rest of the paper is organized as follows. Section II presents brief description of Swarm Intelligence.software & Swarm agents are given in section III &IV. Proposed multicast routing scheme is described in section V. Simulation model and results are discussed in sections VI and VII, respectively. Finally conclusions are presented in section VII.

II. SWARM INTELLIGENCE

Nature's self-organizing systems like insect societies show precisely, desirable properties. Making use of a number of relatively simple biological agents (e.g., the ants) a variety of different organized behaviors is generated at the system-level from the local interactions among the agents and with the environment. The robustness and effectiveness of such collective behaviors with respect to variations of environment conditions are key-aspects of biological success. This kind of systems is often referred to with the term Swarm Intelligence. Swarm systems have recently become a source of inspiration for the design of distributed and adaptive algorithms, and in particular of routing algorithms.

Swarm intelligence is the emergent collective intelligence of group of simple autonomous agents [9][7][8]. Here, an autonomous agent is a subsystem that interacts with its environment which probably consists of other agents, but, acts relatively independently from all other agents. The autonomous agent does not follow commands from a leader, or some global plan. For example, for a bird to participate in a flock, it only adjusts its movements to coordinate with the movements of its flock mates, typically its neighbors" that are close to it in the flock.

Routing algorithms for MANETs must be robust, decentralized, self organized and adaptive. Swarm intelligence based on ants and birds have such kind of characteristics, which inspire us to employ swarm for routing tasks in MANET.

III. SOFTWARE AGENTS

Agent's technology is emerging as a new paradigm in the areas of artificial intelligence and computing[9]. This facilitates the feature for future Internet services and applications development. Agents are said to become the next generation components in software development.

A Software agent is a piece of software that acts to accomplish tasks on behalf of the user. Agents are the autonomous programs situated within an environment, which senses the environment and acts upon it using its knowledge base to achieve its goals. They have certain special properties, which make them different from the standard programs such as mandatory and orthogonal property. Mandatory properties of the agents are autonomy, proactive, reactive and temporally continuous where as orthogonal properties include communicative, learning, believable and mobile. Agent-based programming can be split into two distinctive groups.

IV. SWARM AGENTS

Swarm is a multi-agent system. In which groups of autonomous mobile agents are used for automated collaborative operations. The agents behave as desired without a centralized controller or global information.

The objectives of the Multi agent systems are the coordinated motion, which needs task allocation, Distributed coordination and group communication. The task allocation often arises in multi agent system problems where the "tasks" arise via interactions with the environment and the tasks must be allocated across the agents for efficient execution. The agents are distributed across regions to execute spatially distributed tasks. A group of agents must work together to find and select, as fast as possible, the best task to perform.

V. MANSI

MANSI (Multicast for mobile ad-hoc networks with swarm intelligence) is an on-demand multicast routing protocol. It creates a multicast connection among group members by determining a set of intermediate nodes that serve as forwarding nodes. This set, called a forwarding set, is shared among all the senders of the group. The protocol exploits a core-based technique where each member joins the group via the core node in order to establish a connection with the other group members. The member of the group that has data to transmit becomes core of the group. Other group members join the group via the core node.

MANSI protocol can be described in following steps:

- The first member who becomes an active source (i.e., starts sending data to the group) takes the role of the core and announces its existence to others by flooding the network with a COREANNOUNCE packet.
- Each member node then relies on this announcement to reactively establish initial connectivity by sending a JOINREQUEST back to the core via the reverse path.
- Nodes who receive a JOINREQUEST addressed to them become forwarding nodes of the group and are responsible for accepting and rebroadcast non-duplicated data packets.

- To maintain connectivity and allow new members to join, the core floods COREANNOUNCE periodically as long as there is data to be sent.
- The forwarding nodes form a mesh structure that connects the group members together, while the core serves as a focal point for forwarding set creation and maintenance.
- MANSI adopts the swarm intelligence of ant metaphor to allow nodes to learn a better multicast connection that yields a lower forwarding cost.
- Each member who is not the core periodically deploys a small packet, called a FORWARDANT, that opportunistically explores different, and hopefully better paths towards the core.
- If a FORWARDANT arrives at a node who is currently serving as a forwarding node for the group, it turns itself into a BACKWARDANT.
- When the BACKWARD ANT arrives at each intermediate node, it estimates the cost towards the forwarding node.
- The computed cost, as well as a pheromone amount that is inversely proportional to the cost, are updated on the node's local data structure.
- These pheromone amounts are then used by subsequent FORWARDANTs that arrive at this node to make a decision which node they travel next.

A. Multicast routing agency

The proposed scheme consists of a multicast routing agency at every node in the network. The multicast routing agency comprises of swarm agents called as FANTS and BANTS and a routing knowledge base for maintaining route information. The functional architecture of the model is shown in figure 1. Now, we describe each component of the multicast routing agency.

Routing knowledge base: it is the database, which maintains the routing information that can be read and updated by the swarm agents. The parameters stored in routing table are as follows.

- Join table: maintains a list of nodes that have request ed to join the multicast group via the node. This table is updated when node hears a JOINREQUEST pack et intended to itself.
- Phermone table: maps the neighboring nodes and thei r heights to pheromone intensity.
- Bestcost table: keeps track of how close the node thin ks it is to forwarding nodes in terms of path costs.

Swarm Agency: there are two types of swarm agents, namely, FANTS (forwarding ants) and BANTS (backward ants). The FANTS are the mobile agents, which migrate from node to node to discover the best route in forward direction. BANTS are the mobile agents, which migrate in the reverse path to the FANTS to confirm the best path and update the routing table at each of the visited intermediate nodes (forwarding nodes).

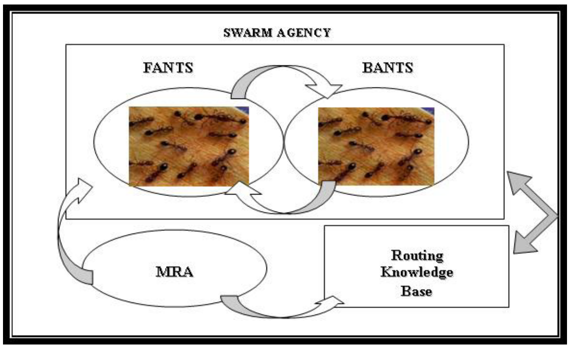

Figure 1. Multicast routing agency framework at a node in MANET

- Forwarding ANTS (FANTS): are used to explore new paths in the network. They measure the current network state by means of trip times, hop count or euclidean distance traveled for instance. They are initiated toward randomly selected geographical locations. In our scheme we chose to assign the node ID of the next hop.
- Backward ANTS (BANTS): serve the purpose to inform the originating node about the information collected by the forward ant. Since they carry additional data from the forward ants they are able to update both forward and backward paths at the same time. The destination node extracts the experienced trip time and hops count, and puts it into the backward ant.

B. Functioning of the scheme

For an explanation of the proposed scheme, a two-dimensional environment grid is considered. Mobile nodes are scattered on the grid. Each ant is modeled as autonomous software agent, which is able to hop from node to node. The size of the multicast group is predefined. The sequence of steps that take place to find the multicast routes using the proposed scheme are as follows.

- Any active source of the group that is the node which has the data chooses its one hop stable (less mobile) neighbor as a core and announces that as a core for it by sending COREANNOUNCE packet.
- The member nodes that receive the packet respond b y choosing their cores and send COREANNOUNCE packets.
- The chosen cores use FANTs to find the path to other cores. FANTs once reach the target core generates B ANTs that move in the reverse direction and update t he routing knowledge base (pheromone table). Phero mone intensity of the link through which backward a nts visit increases. Thus routes between the cores are discovered.
- Each member node then relies on the core to esta blish initial connectivity by sending a JOIN REQ UEST. The forwarding nodes deploy the swarm agen t FANTs to find best path to connect group member a

fter finding all possible paths.
As shown in the figure 2. The multicast group consists of four members A, B, C and D. These members are connected with multiple cores. The multicast member A is connected to core 3 via a forwarding node. The member B is connected to core1 with single forwarding node. C and D are connected to core 2. The multicast tree of four members with multiple cores is constructed for multicasting in MANETs by using swarm intelligence.

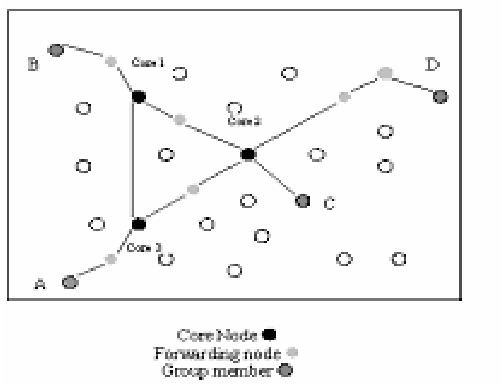

Figure 2. Example of multicast connectivity among four group members.

Each selected core deploys CORE ANNOUNCE packet to find forwarding nodes which connect the group members. Each forwarding node sends FANTs to find best path to connect group member, The FANTs finds all possible paths and returns as BANTs with route information such as cost and pheromone intensity on each path. The cores will select best path and establish the connection with the members of the group.
End

VI. SIMULATION MODEL

An ad-hoc network of 'N' number of nodes is generated by using random placement of the nodes in an area of length 'l' and breadth 'b' meters. The transmission range of each node is denoted as 'R' meters. The speed of movement of individual node ranges from 'x' to 'y' m/sec. Each node starts from a random location and moves in any one of four directions North, East, West or South with predetermined uniform speed towards the boundary. Bouncing ball mobility model is used. In this model, node starts of at random position within the field. Each node then chooses a random direction and keeps moving in that direction till it hits the terrain boundary. Once the node reaches the boundary it chooses another random direction and keeps moving in that direction till it hits the boundary again. Multicast group size (G) of nodes is predefined and any node can become member of the group. Traffic generation comprises of background load and the traffic sources of group members. Gilbert Error model is used to generate transmission errors.

The simulation is done on a Pentium IV machine by using C programming language. To illustrate some of the results of simulation, the inputs considered are as follows. N= 40, l = 640, b = 480, R=100, G =9, x=5, y = 25, background (BKLD) varied from 20 to 60%.

VII. RESULTS AND DISCUSSION

The performance parameters measured are as follows.

- ***Packet delivery ratio:*** it is defined as the ratio of the number of non-duplicate data packets successfully delivered to the receivers to the number of packets supposed to be received. This metric reflects the effectiveness of a protocol.
- ***End to End Delay:*** It is the average time taken to deliver packets to every member of the group. This metric reflects message latency.
- ***Route Discovery Time****:* it is the total time taken to find route from source to all members of the Multicast group.

Figures 3, 4 and 5 show the comparison of performance of MANSI Protocol (which is single core based multicasting protocol by using swarm intelligence) with the performance of proposed work (which uses multiple cores for multicast routing using swarm intelligence).

Figure 3 depicts that packet delivery ratio varies with mobility and BKLD (Background load). The packet delivery ratio is 100% for 20% BKLD with 5 mts/sec mobility for proposed work, where as packet delivery ratio is 80% for 20% BKLD with 5mts/sec of mobility for MANSI.

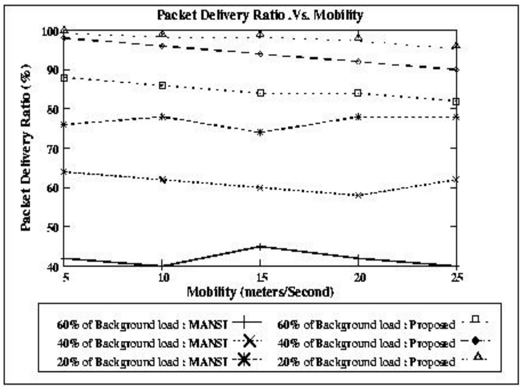

Figure 3. Packet Delivery ratio Vs Mobility.

Figure 4 depicts that end-to-end delay increases as mobility and background load increase. End-to-end delay increases from 15msec to 20msec as mobility changes from 5mts/sec to 25mts/sec with 20% of BKLD and 25msec to 30msec for 60% of BKLD for proposed work. Whereas end-to-end delay is increased from 15msec to 25 msec with 20% of BKLD and 25msec to 35msec for 60% of BKLD, as mobility changes from 5mts/sec to 25mts/sec for MANSI protocol. We can observe that end-to-end delay linearly increases with mobility and background load. Thus, message latency is reduced in proposed work as compared to MANSI protocol.

Figure 5 depicts that route discovery time varies with BKLD and mobility. The route discovery time varies from 35msec to 50msec as mobility changes from 5mts/sec to 25mts/sec with BKLD 20% for proposed scheme. Whereas the route discovery time varies from

25msec to 45msec with BKLD 20% as mobility changes from 5mts/sec to 25mts/sec for MANSI protocol. Thus, route discovery time is more for the proposed work as compared to MANSI protocol due to multiple core selection.

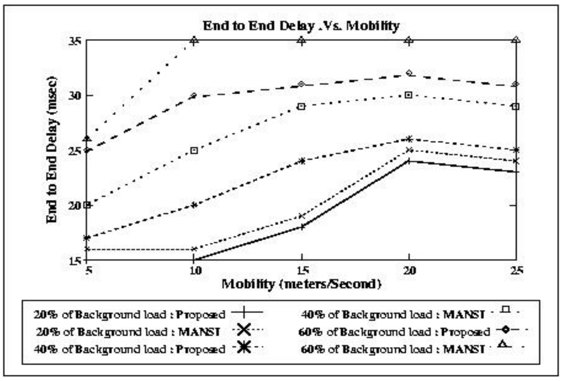

Figure 4. End to end delay Vs Mobility

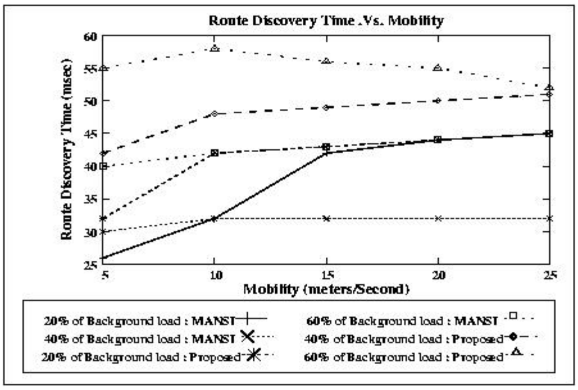

Figure 5. Route discovery time Vs Mobility

CONCLUSIONS

Inspired by swarm intelligence, we have introduced an alternative approach to solving the multicast routing problem in mobile ad hoc networks. Multicasting with multiple cores by adopting swarm intelligence is an on-demand multicast routing protocol that creates a multicast mesh shared by all the members within each group with other members. Ant agents are used to select multiple cores and these cores use ant agents to establish connectivity with group members. Multicast with multiple cores will support the large scale Distributed Virtual environment (DVE) applications used within mobile ad hoc networks. A simulation result shows that this approach provides better message latency and message delivery compared to MANSI protocol, which uses the single core to establish connectivity with multicast group. Multicasting with multiple cores by using swarm intelligence can be applied with other objectives such as load balancing, energy conservation, and security as future work.

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