Mobile Agent Based Message Communication in Large Ad hoc Networks through Co-operative Routing using Inter-Agent Negotiation at Rendezvous Points

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Abstract:- The wide availability of mobile devices equipped with wireless communication capabilities together with the technical possibility to form ad hoc networks paves the way for building highly dynamic communicating communities of mobile users. A key challenge is how to deliver messages in such networks incurring least routing overhead. Cooperative routing is a mobile-agent assisted team approach, which utilizes a set of fixed cluster head nodes to provide proper coordination and cooperation for exchanges and sharing of messages in the team. Our routing strategy aims at reducing routing overheads, message traffic and unnecessary random node visits in the network for delivering data. This routing protocol involves no proactive or reactive routing information overheads and as such the route decision only needs proper coordination and communication among the agents. The main benefit provided by cooperative routing is considerable network traffic reduction at high load. We highlight the main components of the system and discuss the agent life cycle in detail together with the parameters and strategies governing the migration of agents, their merging and termination.

1. Introduction.

A mobile ad hoc network is a multihop wireless network in which nodes can communicate with each other without support of any existing infrastructure. This type of network is fully autonomous and can be set up anywhere any time. An interesting application in such an environment is decentralized rapid message delivery services while incurring the least routing overheads. For this environment to operate properly several of the well-established protocols at the different telecommunications layers are revisited. But most of these protocols are based on flat architecture and the overhead increases considerably with the network size and traffic.

In this paper we propose a mobile agent - based cooperative routing protocol for delivering short messages in a large clustered network whose performance increases with the increasing traffic in the network due to high degree of cooperation among the agents. In our previous works [1,2, 3] the mobile agents were used to deliver messages where they acted as a messenger that will migrate from a source to a destination individually to deliver the message. Thus when there are a number of sources to send messages to a common destination simultaneously, a group of parallel redundant traffic vested with similar responsibility will be generated. This traffic will eventually consume the bandwidth and other crucial resources of the ad hoc wireless network.

The novelty of this work is the introduction of a cooperating agent team that will meet and merge all the individual agents carrying messages for the same destination into a single agent. The agents, which are relieved of their responsibilities in the process, will be terminated if possible and thus reducing the traffic load heavily.

This mode of cooperation can be made clear from the fig 1. If the three agents coming from three distinct sources (4, 7, 5) and having a common destination (15) are able to meet at a common node (8) simultaneously then only any one of the agents will be sufficient to carry all the messages to the proper destination. Thus our routing scheme utilizes cooperating mobile agents where a collection of independent mobile agents come together for the purpose of cooperative task- oriented behaviors like sharing of each others responsibilities, exchanging network information. All these cooperation essentially works directly through inter-agent communication. The entire algorithm works on the fact

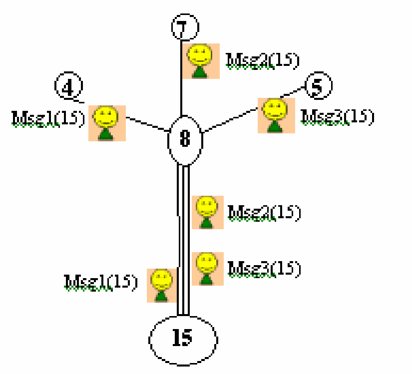


Fig.1a. Delivery of messages without cooperation

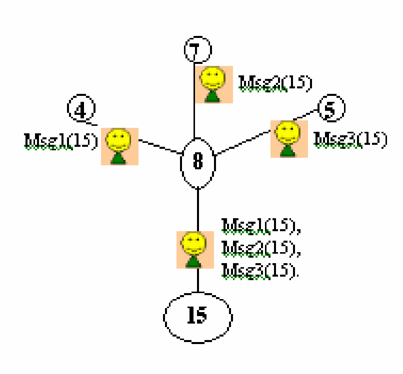


Fig.1b. Delivery of messages with cooperation.

that agents "need to be on the same place at the same time" i.e. they must know the existence of each other.

Now in our work to extend the chance of meeting of the agents we have made arrangement of meeting points at the fixed cluster heads distributed randomly within the network. Agents navigating through the network for delivering messages must visit these cluster heads whenever they are entering a new cluster domain and there by increasing the degree of spatial coordination (agents must be on the same place). The temporal coordination (agents must meet at the same time) has been enhanced with the introduction of a short waiting delay offered to each mobile agent by the cluster heads. This waiting time will further increase the chance of meeting with other agents and can highly reduce the agent-chasing problem. The meeting place hosted at the cluster heads can be called as the *Rendezvous points* within the network and the detainment period of the agents can be called *Rendezvous periods*.

This *Rendezvous points* actually offer a temporary space to be used by all agents for sharing network knowledge, and exchanging messages. Thus when an agent comes a fresh it can exploit all other agents who are currently experiencing their *Rendezvous periods*. Here the traveling agents are allowed to carry the information of already visited clusters along with them. The idea behind this is to capture and share the partial network information present with roaming agents. The integration of all such partial information at a common *Rendezvous point* helps cooperative tasks like taking the decision for next destination, suitable exchange of messages between agents, getting up-to-date knowledge of the network and reducing unnecessary redundant visit of nodes.

Thus we have modeled a cooperative decentralized system where the autonomous agents will be able to deliver short messages within a large network with the cooperative communication between them at suitable *Rendezvous points*. There is no need of knowing the routes proactively or reactively where most of the scarce network capacity is used for exchanging huge chunks of routing table data . The rest of the paper is structured as follows. We discuss some related design view of the proposed framework for message communication in section 3. The cluster heads and their functionalities are discussed in section 4. Agents and the message delivery using cooperative routing protocol has been described in section 5 and 6. Simulation results are presented in section 7 to evaluate the effective ness of the scheme. The paper is concluded in section 8.

2. Related Work.

The lack of infrastructure with multihop connections and constantly changing topology pose difficult challenges on the routing protocols for mobile ad hoc wireless networks. Several routing protocols have been proposed for these networks recently.

These routing protocols can be classified into three categories: proactive, reactive and hybrid. All these existing protocols suffer from inherent short comings .The existing reactive routing schemes introduces an initial delay in actual communication for launch of route discovery while proactive schemes continuously update the routing tables consuming large portion of scarce network capacity for exchanging huge chunks of routing data table. This may not be suitable for real time short message delivery service in a high traffic scenario. Mobile agents are a novel effective paradigm for distributed applications, and are particularly attractive in a dynamic network environment [5,6,7,8]. Mobile agents can be used for efficient routing and topology discovery. In scenarios where pure ant –

based routing schemes are used the nodes have to wait to start message delivery, till the ant agents provide them with efficient routes to various destinations in the network. Another problem is that the nodes carrying ants suddenly may get disconnected with the rest of the network and thus the amount of ants left for routing are reduced which leads to ineffective communication. Even in Ant-AODV hybrid protocol [11] the over head at zero traffic load is significantly high because there will be ants still traversing the network for route discovery generating route reply messages continuously. The previous works done using mobile agents in ad hoc wireless network are mostly unsuitable for large network area and they have their own limitations in handling high traffic load [9, 10, 14].

The current paper tries to overcome these shortcomings by introducing a group of highly cooperating autonomous agents that will be able to communicate data and discover destination route as well, utilizing negotiable information exchanges. This agent-based system has been properly simulated in close resemblance to ant colony but without the concept standard stigmergy, in which agents used to populate caches of nodes with information [5, 6, 7]. Thus our particular interest is to develop an agent based message transfer and navigation protocol without involving the initial delay of route discovery and updation of route table. The particular technique also ensures minimal consumption of network resources.

3. Proposed Framework for Message Communication.

A hierarchical clustering architecture offers several advantages in mobile ad hoc networks. The partitioning of networks into clusters improves routing and mobility management increases system capacity, reduces signaling and control overhead that makes the network more scalable [10,13]. Such architecture is relatively stable due to the localized nature of route computation and can be used in a large mobile ad hoc wireless environment.

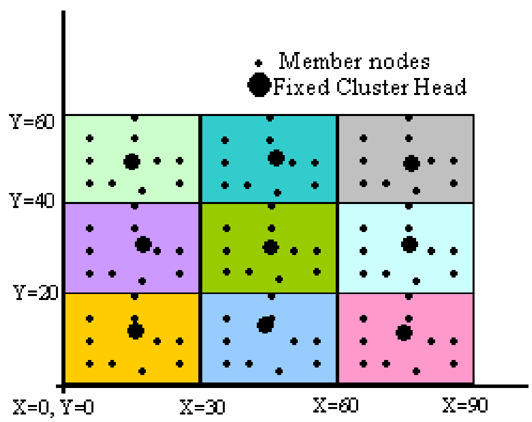


Fig. 2a. Geographically partitioned network.

Motivated by the advantages of clustering we have proposed a framework consisting of a collection of clusters of mobile nodes. To gain benefits from clustering, it is important to keep clusters as stable as possible as frequent changes in clustering architecture can cause high communication and routing overhead. We have assumed of a wireless ad hoc network where each node is equipped with GPS (Geographical Positioning System) for extraction of geographical co-ordinates, routing and direction of movement of each node [9]. To support the idea of stable adaptive clusters we have assumed cluster heads to be fixed and have distributed some fixed nodes as our cluster heads over a geographical area covered by ad hoc wireless networking infrastructure (randomly placed autonomous nodes). These fixed stationary nodes are then allowed to form clusters within a specific geographical boundary from their own geographical coordinate position. The philosophy of forming the clusters is a fixed node with say coordinate (X=40, Y=30) forms a boundary with X=X+15 to X=X-15 and Y= Y+20 to Y=Y-20, thus it forms almost rectangular partitioned overlapping clusters are formed. The geographical overlapping boundary causes no problem as the member node accepts the nearest cluster heads as their leaders. Initially, a Hello message consisting of the GPS of the fixed node and boundary notification values is broadcast for gathering membership information for forming the clusters. The nodes whose GPS lies within the boundary domain in turn send their node identity number along with their GPS to the cluster head. All packet transfer take place through geographical routing i.e. knowing the GPS of the destination the route decision to the next hop must minimize the geographical path length between source and destination [2,7,8]. The node densities of the fixed nodes are kept relatively high to avoid partitioning of the network.

Node Identification no: (n)	
Current Location	(Xn ,Yn)
Location of cluster Head	(Xch,Ych)
Cluster Head Identification	CH
Cluster Boundary Information	(Xleft, Xright) (Yup, Ydown)

Fig .2b. Structure of a node.

Thus our-clustered network consists of cluster heads (acting as a base station for the cluster) and ordinary nodes as well. All the identical nodes in the entire network will be having a unique node identification number. The structure of a node used is given in fig 2.b. Once the clustering architecture stabilizes through out the network each cluster head starts sending periodic messages to collect the member node identification number to maintain a complete updated knowledge of its members. When a member node becomes mobile it informs the cluster head about its migration and on traveling to a new region boundary it will send request packet to the current cluster head for membership. Thus our cluster heads are vested with the responsibility of keeping neighborhood integrity record with periodic refreshment.

4. Functionalities of cluster heads.

The functionalities of the cluster head are specifically designed for providing maximum cooperation with the mobile agents and also to act as the mail server within the cluster. The responsibility vested on to a cluster head can be classified under the following headings

4.1 Membership List Formation, Modification, Delegation.

At first the cluster head starts broadcasting its GPS to all the members. Each member node in turn sends back their node identification number and their corresponding GPS along with the acknowledgement packet. Thus the cluster head becomes able to create a ready list of information for all the nodes belonging to its region. The membership list consists of the node identification number and the corresponding GPS of all the member nodes. This lists maintained at each cluster head are updated periodically to keep track of the changing coordinates of the mobile nodes. The structure of a cluster head node is given in figure 3. The cluster head also periodically unicasts the cluster binding information packet to all the listed nodes so that the receiver gets informed about the current cluster head.

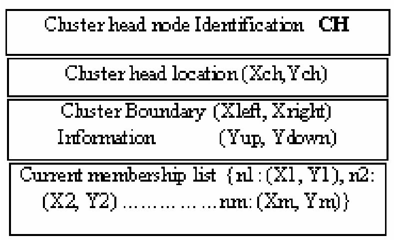


Fig.3. Structure of a cluster head.

4.2 Accepting and delivering of messages by cluster head.

The cluster heads are responsible for accepting messages from the agents. Each cluster head will be given a temporary workspace with which to perform its functions. The temporary workspace will also to allow multiple mobile agents to co-exist and communicate. The cluster head learns the status (destination node identity) of each messages carried by mobile agent, and if the status matches with the list maintained by the cluster head the message is accepted at once and get delivered to the destination node with point to point message delivery scheme. When no match is found the mobile agents is allowed to stay at the same cluster for the *Rendezvous period* for sharing and updating of network information.

4.3 Handling mobile nodes by acting as temporary mail servers.

When a node crosses a region boundary (knows the boundary coordinates) i.e. it is no more able to receive any binding updation packet from the current cluster head it informs the cluster head about its migration. The cluster head can buffer all interim messages coming for this migrating node temporarily. If the node comes back by this temporary period and informs the cluster head about its arrival the cluster head at once delivers the stored message. But if the node does not come back to its own cluster within the specified time the cluster head will delete all the entries related to that migrating node from its membership list. This way, a cluster head can also act as a temporary mail server for the mobile member nodes.

5. Features of cooperating mobile agents.

In this paper we introduce mobile agents to hop around the network for delivering messages .The agents are allowed to meet with other agents at some fixed meeting places or *Rendezvous points* as has been mentioned. The meeting will mutually benefit each other by cooperating in delivering messages. In this current flexible and decentralized framework any autonomous node can send message to any other node at any instant within the network by just issuing a mobile agent. The agent then carries the message to the corresponding cluster head. The cluster head then becomes responsible for delivering the message to proper destination. Analog to the real life, these agents actually play the role of messengers and the cluster heads play the role of post offices in the ad hoc wireless scenario. The cooperating agent scheme has been explicitly designed to reduce the agent traffic in the network. The unnecessary redundant node visits made by the agents moving for a common destination has been avoided by sharing and merging with other agents. These agents together with the cluster heads take the responsibility of providing communication services and improvement of overall traffic coordination in the network.

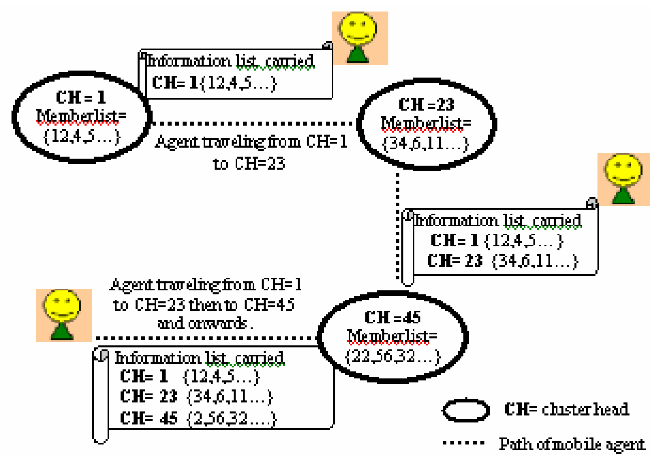


Fig. 4. Information collected and carried by mobile agents.

5.1 Information carried by mobile agents for extending cooperation.

While delivering messages a mobile agent will maintain the path records of all the visited clusters and its corresponding members. The philosophy behind carrying of this network information is to provide cooperation (will be discussed in section 5 in detail) and share the updated network knowledge with other agents who have not visited those clusters. As this information field carries mere numeric values this membership list collected from each cluster head can be easily carried using packets of permissible lengths.

In few cases the length of the information list carried by an agent gets longer due to the course of journey made by an agent to reach the proper destination. The phenomenon of cascading of the list has been restricted using the hop count limit as this may include a huge chunk of data to be carried along by a mobile agent. No mobile agent is allowed to travel forward further whenever its hop count has got exhausted and it is compelled to move back to its originating cluster head. Thus whenever an agent has finished its forward journey it will eventually follow the same path back to the source cluster.

5.2 Navigation policies followed by mobile agents.

The objective of the navigation procedure is to minimize the distance between the agent’s current location (current location of the node where the agent is residing) and the cluster head location. This criterion would enable a mobile agent to select a neighbor of its current location and migrate there. If there is no neighbor available at that instant of time satisfying the above-mentioned criterion, the agent waits for a pre specified amount of time and tries again. Because of high degree of mobility, the topology will change and it is assumed that the agent will eventually succeed to migrate [5,7].

Whenever a mobile agent wants to leave its current cluster for delivering messages to some unknown cluster it will collect the membership list information from the cluster head and will try to reach for a boundary node through which it may get an exit point. The node lying at the boundary will have neighbors from two or more different clusters and can act as gateway nodes. Our work does not need to keep additional information for gateway nodes in the cluster heads. Thus if an agent can reach such a gateway node it can cross the cluster boundary easily and can start visiting a fresh cluster head. As the location of the cluster head can be made available from any node of that region it can easily track the new cluster head there, which has been compulsory. Though the order of cluster visits take place in a random manner still the redundancy in the path visit has been avoided by maintain the path visit list. The agents are free to roam among the clusters within the network in a random manner.

5.3 Creation and termination of mobile agents.

When a mobile node within the ad hoc network wants to send some message, it immediately creates an agent. Each such agent attaches with itself a bag to carry the message. This message bag is of a given capacity, which can be made full or can be made empty. The node after initiating the agent puts the message in its bag. The mobile agents are able to exchange these messages with other mobile agents on having suitable cooperation with them, which will be discussed subsequently. These agents will be terminated automatically when there is, no more messages to deliver and their bags are empty.

6. Co-operation between agents for effective message delivery.

The entire routing protocol is based on coordination and cooperation among the mobile agents. As the number of agents increases with the number of messages in the system the degree of cooperation and sharing among the agents will surely increases. The overall performance of the message delivery scheme gets benefited from this cooperative sharing and that has been truly realized in the simulation and results.

6.1 Mobile agents at *Rendezvous points*.

When an agent visits any cluster head the cluster head cooperates with the agent by allowing it to consult the membership list maintained by it .The cluster head will further take the responsibilities of delivering the messages if the mobile agent has any message for this local cluster. If that agent has no more messages left in the bag then it will be terminated instantly. In this way, any agent may become aware of the members of the cluster at once it visits and consults the cluster head. If a mobile agent does not have any message to deliver to the current cluster head (*Rendezvous point)* then the cluster head will host the mobile agent for a pre specified period of time *(Rendezvous period)*.

The main idea behind the detainment of any agent is to give it a fair chance to meet with other mobile agents currently present in the system. The *Rendezvous period* offered at the *Rendezvous points* will not only extent the temporal as well as spatial coordination among the agents but will allow to overcome the problem of chasing of agents from node to node.

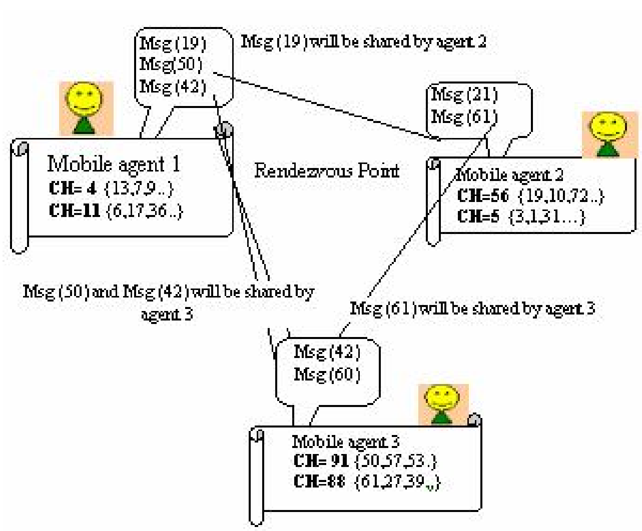


Fig. 5. Cooperative message exchanges at Rendezvous point.

6.2 Inter-agent cooperation.

During *Rendezvous period*, if a mobile agent meets another mobile agent they may freely consult their already visited path records. This sharing of network information will able the agents to have free consultation on the visited clusters along with their members. The agent starts passing on the undelivered message of one agent to another if the destination node of one's message lies on the back home journey path of another.

This cooperative view is clear from fig .5, where agent 1 handovers messages destined for node 42, 50 and agent 2 handovers message with destination 61 to agent 3, as the back home journey list of agent 3 contains cluster head 91 with member 50 and cluster head 88 with member 61 respectively. Agent 3 will further extend the level of cooperation by accepting the message for node 42 as it has got a message in its bag for the same destination node. Agent 2 also cooperates with agent 1 by sharing its message for node 19. In such a situation, one mobile agent may be relived from all its burden of messages by emptying its bag and will consequently be terminated. In the above figure agent 1 has emptied its message bag due to the cooperation it has obtained at the *Rendezvous point* and will be killed at once.

This cooperation and sharing of load may reduce huge amount of routing overhead and unnecessary agent traffic as a whole. The number of messages one agent can carry has been limited by the size of bag attached with it to avoid overloading of a single agent. If the mobile agents do not find any suitable agent partner for exchange during its *Rendezvous period*, it will again start navigating from host to host in search of proper destination. The over all cooperative routing scheme can be described with the following algorithm.

6.3 Cooperative Routing Algorithm:

Step-I : A node N wants to send a message **M** with destination address **d.**
It will issue a mobile agent; // Every autonomous node is able to issue agents.
Bag of the mobile agent = msg **M** ; // Attaches the message with the agent.
The agent starts travel to its own cluster head by choosing the shortest path by tracking through GPS. // Each node knows the GPS of cluster head

Step-II : The Cluster head registers the mobile agent with a unique identification number **A**;
Marks the status of agent **A** = living;
Loop // Allow to consult its own member list first
For all the messages in agent **A**'s bag
Case I: If (destination **d** of any msg **M** = a member node of the cluster)
{ Agent **A** hands over the msg **M** to the cluster head.
Cluster head unicasts the msg **M** within the cluster to the destination **d** tracking the GPS. // Cluster head knows the GPS of all member nodes.
If (there is no more message in the agent's bag)
Kill Agent **A**; // The Agent with a empty message bag will be terminated.
Mark Status of **A** = dead; }
Until (more messages are there)
Else
Case II: Initiate *Rendezvous period* for agent **A**;
Loop
{ For all other living mobile agents already waiting at the cluster head and also for the new agents coming within the pre specified *Rendezvous period*
check the cluster visit record of other living agents;
if (the agent **A** has any msg for the nodes of the regions that other mobile agents with which it meets has already visited)
then transfer the msg **M** to that corresponding mobile agent's bag ;
} // Suitable message exchange will take place during *Rendezvous period.*
If (any of the mobile agent's bag becomes empty in the process of exchange)
{ Kill the agent with empty message bag ;
Mark Status = dead // Reduction of redundant Agent Traffic. }
Until (Rendezvous period exists)

Case III : If (any mobile agent exists with status = living and its *Rendezvous period* is over)
Then the agent **A** collects the current cluster head member list;
// Attaches with the already visited cluster path information.
If (the hop count for forward journey of the agent has exhausted)
Start back home journey by popping the visited list.
Else
Start journey to other unvisited regions. // Start tracking the boundary nodes by knowing the boundary information from the cluster head and when new cluster head reached
Goto **step I.**

7. Performance evaluation.

In this section, we evaluate the performance of the cooperative routing scheme for short message delivery within an ad hoc wireless network setup. We first describe our simulation implementation, performance metrics and methodology, and then we evaluate the node initiated message delivery scheme. The results confirm that the cooperative routing algorithm using *Rendezvous periods* at *Rendezvous points* and are very efficient in delivering messages under high traffic. The result will also show that though at the beginning there will be as many living agents in the system as there are messages but through suitable exchange and message sharing the number of living traffics get considerably reduced with time.

7.1 Metrics and methodology.

The network used for the simulation consists of 1000 nodes in a 500m X 500m simulation area. The movement of the nodes is made random. Nodes are allowed to move at speeds between 0 and 30m/sec. The performance of the entire routing protocol are evaluated using the following two criteria:
i) Number of messages in the system i.e. the total number of mobile agent traffic issued by the nodes in the network.
ii) The time period selected as *Rendezvous period* for the network.
The performance of cooperative routing is greatly influenced by these two parameters as our routing scheme depends on the degree of cooperation that can be obtained from other agents. We vary these two parameters and determine their effects on the required number of node visits and average end-to-end delay for message delivery. Fig. 6a shows the result when there are 1 to 900 mobile agents in the system with *Rendezvous period* varying from 0 to 5 simulation time units.

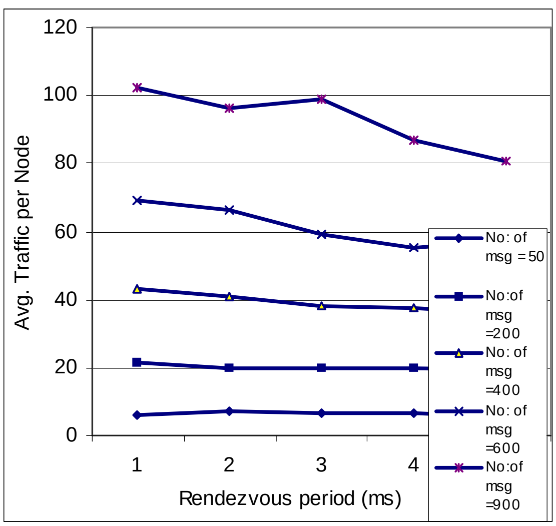


Fig. 6a. Average traffic reduction in the network with increasing Rendezvous period.

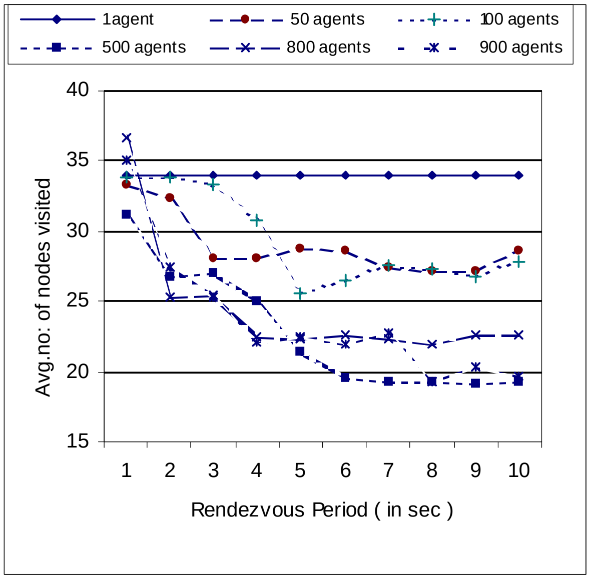
7. 2. Impact of *Rendezvous periods* on network traffic.

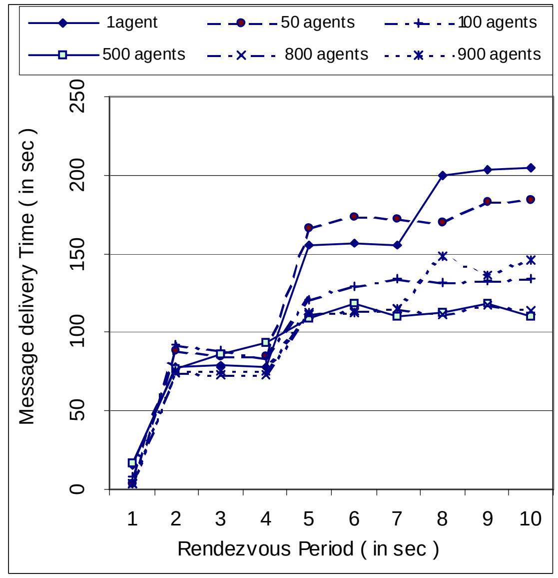
The impact of *Rendezvous periods* on network traffic can be easily understood when the load in the network is considerably high. Initially the number of messages and the number of agents to deliver them remain equal in the network. But with time as the agents start meeting at various *Rendezvous points* (cluster heads) within the network quite a large number of agents are able to terminate themselves through suitably message exchanges and handovers.

This impact can be made clear by extending the agent waiting periods (*Rendezvous periods)* at each *Rendezvous points*. Thus due to the reduction of network traffic at each cluster head the overall traffic handled by each node also gets heavily reduced. From fig. 6a it is clear that this impact can not be at all realized for graphs at very low loads like when no: of messages in the network are 50 or 200. But as the load has been increased from 400 to 900 the over all traffic reduction is very prominent which again increases with increase in *Rendezvous period*.

7.3. Impact of *Rendezvous period* on node visits.

A larger *Rendezvous period* ensures that a mobile agent can stay longer in a cluster head and as such the chances of meeting with other agents should increase. It is clear from the graph shown in fig 6.b that when there is a single agent in the system there is no impact of any *Rendezvous period* at all. But as the number of agents increases the degree of cooperation among them also increases and the number of unnecessary node visits decreases due to the merging of redundant agents traveling towards same destination. These required node visit gets reduced further with the increase in *Rendezvous period* i.e. with increase in chance of agent meeting. Thus the avg. number (number of hops required to deliver single message) of node visits required to deliver 500 messages in the network reduces from 31.225 to 20.434 with the increase of *Rendezvous period* from 0 to 5 simulation secs. When the *Rendezvous period* is increased more than 5 secs almost all the graphs of high or low traffic become flat. These flat nature can be explained from the fact that within the period of 5 secs all the agents have reached a





saturation point of

Fig.6.b Average number of node visits with Rendezvous Period

Fig. 6c Average message delivery time with Rendezvous Period.

their cooperation level i.e. if they are allowed to stay longer no more considerable message exchange can take place.

7.4 Impact of Rendezvous period on message delivery time.

The graph of figure 6b. gives the average end to end message delivery time with varying *Rendezvous periods*. Initially there is a sharp increase in message delivery time from 5.7 secs to 69.7 secs with *Rendezvous period* = 0 to *Rendezvous period* = 1sec. After this initial hike in delivery time all the graphs of different message load settle down to a particular delivery time i.e. there is no sharp increase in message delivery time with *Rendezvous period*. Thus the maximum level of cooperation among the agents can be realized for *Rendezvous periods* of 1sec to 4 secs. Further increase in *Rendezvous period* (after 4 secs delay) only lingers the message delivery time for enhanced waiting time introduced at each cluster heads. Thus this *Rendezvous period* of 4 secs can be considered here as the threshold value after which all the curves of varying number of agents rises like step function due to the increase of *Rendezvous period* at each level. So the graph clearly shows the fact that with the introduction of *Rendezvous period* the cooperation level and as such the throughput of the message delivery scheme highly increases but the messages are delivered a little late.

7.5. Impact of mobility:

With the increase in mobility from 10m/sec to 30m/sec the end-to-end message delivery time and average node visits required to deliver a message has increased a little. Here we have assumed the cluster heads to be stationary. When a node is becoming mobile it informs the cluster head about its migration and the cluster head on its part temporarily stores all the interim messages for these node. If the node comes back within a short while the cluster head immediately sends the message to the node. Using this particular scheme we have noticed that the message drop due to mobility can be avoided. On entering a new cluster an agent collects the cluster head GPS from any member node of the new cluster and sends request packet for membership. The cluster head on receiving this cluster binding notice updates its current memberlist.

We have made the mobile agents to wait at the cluster heads when the member list is being updated. This cluster updation period introduces a brief delay in delivering messages but it highly ensures the delivery. From the graph shown in figure 7b. the message delivery time with mobility 30m/sec is higher than the message delivery time with low mobility like 10m/sec. The average number of nodes required to deliver a message also gets increased if the member node is not currently available. In that case after waiting for a pre specified time for the node to come back the cluster head handovers the undelivered message to any one of the agents available at its site. Thus the message begins a fresh journey with the newly attached agent. This case has been encountered when the mobility of the nodes are kept high i.e. 30m/sec.

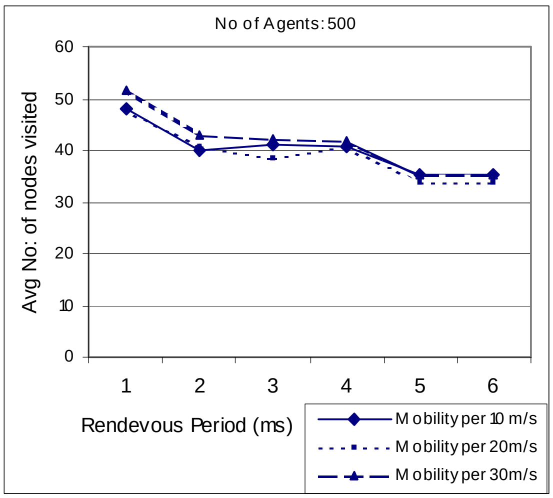


Fig.7a. The impact of mobility on number of node visits.

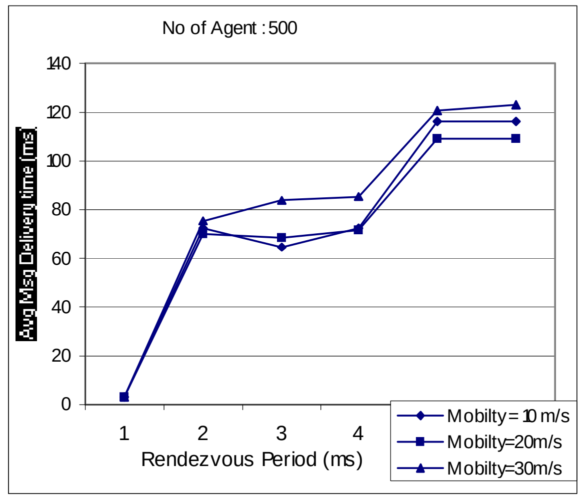


Fig. 7b. The impact of mobility on message delivery time.

8. Conclusion.

In this paper we have developed an agent-based message transfer protocol ensuring minimal consumption of network resources. At first we discussed the problems of existing message delivery services in ad hoc wireless network and presented this cooperative routing approach to address the problem.

This system accomplish the task of delivering messages through groups of cooperative agents and the paper have tried to formalize cooperative autonomous mobile agents through capturing the dynamic character of agent group. Our particular interest is a technique for direct inter-agent communication without consuming large portion of network capacity.

We have evaluated the performance of cooperative scheme on a variety of network conditions. We have shown that because of the property of temporal and spatial coordination, the throughput of data delivery increases and the overhead decreases with high load of data packets. In more dynamic and higher load scenarios our simulation results show that by using a suitable waiting time (*Rendezvous period*) at the fixed nodes (*Rendezvous point*) a significant improvement can be obtained in the number of node visits. The only shortcoming that can be observed here is a brief delay in delivering the messages due to the introduction of waiting periods at cluster heads.

In terms of routing overhead, cooperative protocol generates a relatively decreasing overhead in highly congested scenarios and the impact of *Rendezvous period* is clear from the graph at higher loads. Although mobile agents are used in wireless network like for locating documents [14] but the routing algorithms followed includes large initial delay and huge routing overhead for collecting network information. In essence, cooperative routing may be employed in any large ad hoc wireless network with little overhead. The limitation is the increase in the length of information list carried by each agent and as such these scheme works very well when used for short message delivery services.

Our future work will include addressing the impact of number of *Rendezvous points* i.e. the number of cluster heads on the scheme and as well as completion of the protocol for mobile *Rendezvous points.*

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