Arab Gulf Journal of Scientific Research, 27 (3): 94- 102 (2009)

Research Paper Ref. No 2486

# Location Enhanced Cluster Based Routing Protocol

# برتوكول التوجيه الجغرافي في مجموعة الشبكات الديناميكية

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**Abstract:** A mobile wireless Ad hoc network (MANET) is formed dynamically without a need for a pre-existing infrastructure. This kind of dynamic networks has been used in commercial, cultural, and environmental applications including emergency situations. This paper addresses the problem of the overhead resulting from flooding the control packets in mobile ad hoc networks in searching for routes between the source and destination. We propose a location enhanced routing protocol for clustered MANETs based on the cluster based routing protocol (CBRP). Our protocol employs local position information obtained by smart antennas to discover routes and make routing decisions for the clustered MANETs. Simulation results shows enhancing the performance of clustered MANETs. Simulations show the packet delivery ratio increased, the delay decreased and the control packets overhead decreased.

**Keywords**: *Ad hoc networks, Cluster, smart antenna, CBRP.*

**المستخلص**: شبكات المحمول الديناميكية هي أحد أنواع الشبكات اللاسلكية التي تتكون بطريقة ديناميكية دون أي إعدادات مسبقة و دون الحاجة الى أجهزة مركزية. ينتشر استخدام هذا النوع من شبكات الحاسوب و المحمول في العديد من التطبيقات المدنية التجارية و الثقافية و ايضا في التطبيقات المستخدمة لحالات الطوارئ كالزلازل و غيرها. في هذا البحث نتناول مشكلة الارسال الكثيف لحزم التحكم المستخدمة في البحث عن المسار بين المرسل والمستقبل. في هذا البحث نقدم حلا لهذه المشكلة عن طريق الاعتماد على الهوائيات الذكية التي يمكن من خلالها تحديد الموضع الجغرافي للاجهزة و البحث عن المسار بين المرسل والمستقبل في منطقة محددة من الشبكة بدلا من البحث في كل الشبكة. تدل نتائج هذا البحث على تحسن أداء عمل شبكات المحمول الديناميكية.

**كلمات مدخلية** : *الشبكات الديناميكية، المجموعات، الهوائي الذكي، بروتوكول التوجيه.*

## INTRODUCTION

A Mobile Ad hoc network (MANET) is a self-organizing multi-hop system of wireless nodes that can communicate with each other without pre-existing infrastructure. This type of networks has been used in several applications such as industrial, commercial, cultural and environmental including emergency situations etc. Ad hoc networks are characterized (Mukherjee, *et al*. 2003) by:

- Dynamic topologies and frequent network reconfiguration due to nodes' mobility.
- Decentralized operation: Since there are no centralized entities for network management; Ad hoc networks require more sophisticated algorithms for routing and management.
- Limited resources including power supply, bandwidth, and processing capabilities.
- Nodes communicate over wireless variable-capacity links.
- Multi-hop communication forces nodes

to play multiple roles such as transmitter, receiver, or relay station.

Existing Ad hoc routing protocols are classified either as proactive (Table-driven) or reactive protocols (On-demand) (Royer and Chai-Keong, 1999; Marina and Das, 2005). Proactive protocols always know the routing information beforehand through periodic route updates. Each node maintains one or more tables to store routing information and refreshes these tables timely. Each node propagates its tables through the network to maintain a consistent network view. The advantage of proactive protocols is that each node has nearly a complete view about the network. Once a source wishes to transmit data to a destination, it immediately looks up the routing table for the needed route. However, proactive protocols do not perform well in high mobility or large networks since the amount of information maintained in tables becomes large. On the other hand, reactive protocols create routes only when needed by the source. When the source requires sending to the destination, it invokes the route discovery procedure to discover the route. Once the route is found, it is maintained by the route maintenance procedure until the destination becomes inaccessible. Although the source has to wait for node discovery delay, practical experiments show the reactive protocols perform better and more suitable for Ad hoc networks than proactive ones.

The architecture of the Ad hoc networks can be classified into flat or hierarchal architectures (Haas and Tabrizi, 1998). Flat architectures do not define any network structure. They encounter scalability problems especially with the increased network size. In these architectures each node has to maintain information about all nodes in the network which becomes significantly large with increasing the network size (Yu and Chong, 2005). In hierarchal architectures nodes are dynamically grouped into clusters (Gerla and Tsai, 1995; Lin and Gerla, 1997; Chatterjee, *et al.* 2002). Each cluster has a representative called cluster head (CH). Every node has to join a cluster. A node that belongs to more than one cluster is called a gateway. Figure (1) shows clustered Ad hoc network architecture. Routing traffic between clusters is done by the CH. The CH is responsible on collecting control packets, e.g. route discovery packets, and relaying them. On contrast, in flat architectures each node floods control packets which may overwhelm the network with these packets and consumes the limited capacity.

In this paper we present a location-enhanced routing protocol for clustered MANETs that employs smart antennas for estimating nodes' locations. The rest of this paper is organized as follows. Section (2) presents a description of the smart antenna and how to use it to estimation a location. Section (3) presents the related works. In section (4) we present the proposed protocol in which we employ smart antennas to estimate nodes locations and calculate the relative location of the source by updating the estimated position along the path from the source to the destination. Section (5) discusses the simulation results and finally in section (6) we conclude the paper and outline future work.

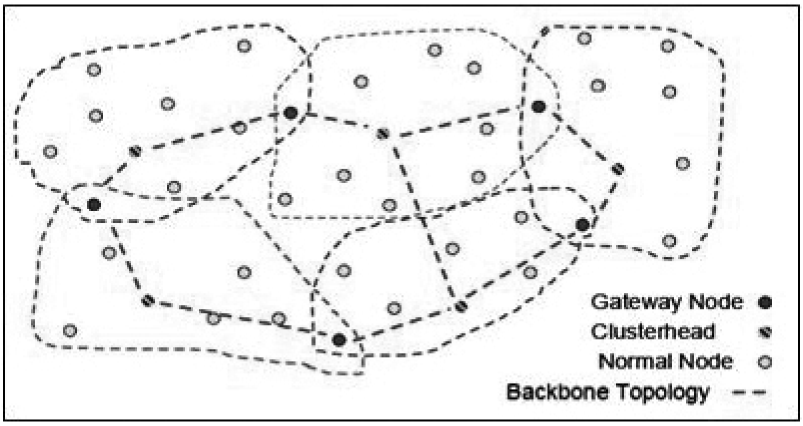


**Fig. 1.** Clustered Ad hoc Network.

**Smart Antennas**

Smart antennas is a system of antenna arrays with smart signal processing algorithms that are used to identify spatial signal signature such as the direction of arrival (DOA) of the signal, and use it to calculate beamforming vectors, to track and locate the antenna beam on the mobile/target. Location estimation using smart antennas is more suitable in MANETs than the global positioning system (GPS). GPS has the following limitations to be used in MANETs:

- GPS is very useful outdoors, but it is ineffective indoors because GPS radio signal is blocked by walls inside building (Enge and Misra, 1999).
- The accuracy of current GPS lacks the precision required by MANETs (Quintero, *et al*. 2007).
- GPS consumes high power while mobile nodes are equipped with limited batteries (Niculescu and Nath, 2003).
- Not all nodes equipped with GPS.

When radio signals arrive at a smart antenna, the antennas in the array collects information on the phase of the signal. This information is processed by an embedded digital circuit. Location information is finally outputted to the host mobile station or terminal. Figure (2) shows two nodes A and B equipped with smart antennas (Quintero, *et al*. 2007). When node A receives signals from B, the array of antennas estimates the Angle of Arrival (AoA). The power of the signals helps to estimate the distance from node B to node A. This information is processed by the digital signal processor to estimate the position of node B. By the AoA ($\theta$) and distance ($d$) a node can easily estimate its neighbor position using the following formulas:

$$x = d \cos \theta, \quad y = d \sin \theta \qquad (1)$$

In order to estimate the position of a non-neighbor node, relative position calculation is applied. In Figure (3) node A can estimate the position of node C by summing the position of node B relative to A, ($P_B^A$), and the position of C relative to B, ($P_C^B$), as declared in (2).

$$P_C^A = P_B^A + P_C^B \qquad (2)$$

for example, in Figure (3 ) node B estimates the position of its neighbor C as (3, 1) and node A estimates the position its neighbor B as (3,-2). Then, if B sends information about the position of C to A, A calculates the position of C as:

$$P_C^A = (3, -2) + (3, 1) = (6, -1)$$

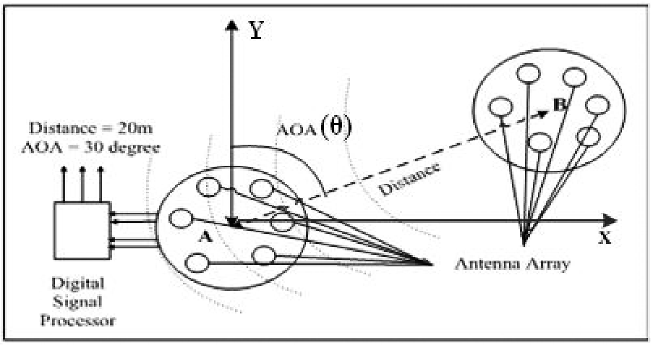


**Fig. 2.** Locate mobile node with smart antenna.

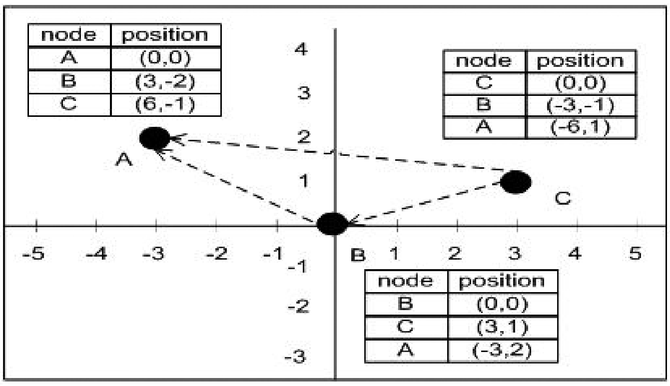


**Fig. 3.** Location calculation.

## State of The Art

Many routing protocols have been proposed for routing data in MANETs. In this section we present three related protocols AODV, CBRP, and LEOD.

- Ad hoc On-demand Distance Vector protocol (AODV) is a reactive routing protocol that is designed for flat architectures (Perkins, 1997; Boukerche, 2001). Each host maintains a routing table to store information on the mobile nodes in the network and how to reach each of them. Flooding is the way which a source finds a route to a destination. If a node A wishes to send to B, A creates a route request (RREQ) message and broadcast it to its neighbors. Each node receives the RREQ re-broadcasts it to its neighbors with increasing the sequence number of the message to prevent looping. When the RREQ reaches the destination B, B replies with a route reply message (RREP) to A. Then A stores the route in the routing table. An intermediate node can reply to node A if it has a valid route to B. Periodic **Hello** messages are used to maintain the routes. By **Hello** messages a node can discover its neighbors. When a node discovers a failure in a link it informs its neighbors. The neighbors also inform their neighbors and so on and the corresponding routes will be deleted from the tables. This protocol works well in small networks with low mobility. In large networks, flooding of control packets overwhelms the network and leads to poor performance.
- Cluster Based Routing Protocol (CBRP) is a routing protocol that clusters the network to reduce the flooding of control packets. CBRP groups the nodes in clusters and elects a CH for each cluster. At any time, a node is in one of three states: a cluster member, a cluster head, or undecided, meaning still searching for its host cluster (Jiang *et al*. 1999; Boukerche, 2001). Each node starts in the undecided state and periodically broadcasts a **Hello** message. Upon receiving a **Hello** message, the CH responds to the node and joins it to the cluster. The node then changes its state to member. As a clustering protocol, CBRP performs better than AODV in medium to large size networks. But, clustering also needs flooding control packets in network especially with high mobility nodes.
- Location Enhanced On-demand routing protocol (LEOD) is an evolution from the AODV protocol (Quintero, *et al*. 2007). LEOD uses smart antennas to localize neighbor mobile nodes. This information is used to estimate the location of the mobile nodes in order to reduce the flooding of the control packets. Assume node A wishes to send to B. Initially A has no location information about B. A floods a RREQ and puts its location information in the RREQ. This location in formation is updated hop by hop till the RREQ reaches B. Then, B will reply with a RREP message back to A. Also, intermediate nodes will store location information about B. When A wishes to send again to B, a will benefit from the location information of B. A will restrict flooding to the request area in which node B exists. Nodes that are outside the request area ignore the RREQ. LEOD protocol efficiently reduces flooding control packets in flat Ad hoc networks. However it does not consider the advantage of clustering. Our work is most related to LEOD protocol. The main difference is that we restrict gathering location information to the backbone nodes in clustered MANETs, i.e. the GWs and CHs. Benefiting from smart antennas in clustered MANETs we significantly reduce the flooding of control packets. Simulation results show the LECBRP outperforms the LEOD protocol.

## Problem Statement

Mobility in Ad hoc networks is the main factor affecting stability of routes. Movements of nodes lead to many disconnections in the routes established between these nodes. In Ad hoc routing protocols, flooding of control packets is the only mechanism to discover and maintain routes. Flooding overwhelms the network with high number of control packets which puts serious questions about the scalability and reliability of the network. Flooding overhead appears clearly in dense networks due to the high number of nodes that broadcast the control packets. Consider Figure (4) and assume the source A wishes to establish a route to the destination B. A

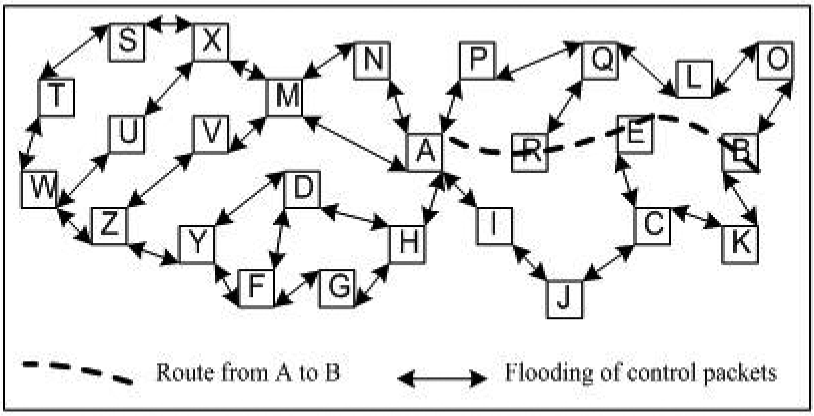


**Fig. 4.** Flooding to whole network to find route AàB.

will overwhelm the whole network with control packets to maintain the route to B. A significant question arises here; why do we flood the whole network to find a certain route? Can we limit the flooding to a specific area of the network in which B is expected to exist thus reduce the flooding overhead?

## Location Enhanced CBRP (LECBRP)

In this section we introduce our proposed solution to reduce the network control overhead in clustered MANETs as much as possible. In our solution, we benefit from both (1) clustering the Ad hoc network by CBRP (Jiang, *et al*. 1999) and (2) estimating the location of the nodes by employing smart antennas. As a cluster-based on-demand routing protocol, LECBRP is an evolution from CBRP, where local position information are employed to aid routing and enhance the performance of the basic protocol. The LECBRP has three major components: cluster formation, adjacency cluster discovery and routing. The routing process is divided into two phases, route discovery (RD) and the actual packets routing. The RD phase is divided into two steps, route request and route reply. Next we present the above components of LECBRP.

**Cluster Formation**

The election of the CH in LECBRP follows the same criteria as the basic CBRP. The nodes wake up in undecided state, exchange **Hello** messages and elect a CH. When a new undecided node receives a **Hello** message from a CH, it joins this cluster. The addition in LECBRP is that each node estimates its neighbor's locations and stores this information in a newly defined data structure called Location Table (LT). This table also stores the relative locations of non-neighbor nodes. An LT entry contains both a node ID and its relative location.

**Adjacent Cluster Discovery**

Each CH keeps Cluster Adjacency Table (CAT) that records information about its entire neighboring CHs. Periodically each node sends a **Hello** which contain a neighbor table (NT) and the CAT. Using the **Hello** messages alone, a CH is able to discover the adjacent CH. An entry in CAT contains the adjacent CH and the gateway node ID through which the neighboring CH could be reached.

**Routing**

Routing in LECBRP is based on source routing as in the base CBRP. It has two phases RD and actual packet routing.

***Route Discovery (RD)***

RD is the mechanism whereby a node A wishing to send a packet to a destination B obtains a source route to B. RD is the main operation that requires flooding of control packets. However, because of the clustering and estimating nodes locations, the number of times a control packet is forwarded much less in general. LECBRP can apply both complete flooding and limited flooding in searching for a route. Complete flooding is applied when the source node A has no previous knowledge about the location of the destination B. Only CHs are flooded with RREQ packets to search for a route to the destination. To perform a RD to B, the source node A sends out a RREQ message with the target node address set to B's address. A includes its default position (0, 0) in the RREQ packet. This RREQ packet propagates along CHs and gateways till reaching B. At every gateway or CH the relative position of A is updated by calculating the position as described in section II and included in the RREQ packet. Figure 5 (A) shows a simple example. We will go through this example to explain the complete flooding process. Node A broadcasts a RREQ which is received by CH1. By accessing the LT, CH1 obtains the estimated location of A relative to its position. Then CH1 forwards the RREQ to the gateways g1 and g2. Each of g1 and g2 compute the source A by formula (2). When the RREQ reaches B, B can estimate A's position from the CH, GW, CH … nodes that forwarded the RREQ. Then B updates it LT to contain the relative position of A. When the target of the Request, node B, receives the RREQ, B sends out a route reply (RREP) packet to A which includes the list of Cluster Addresses the RREP should traverse in order to reach A. The RREP also contains the position of B relative to A. While forwarding the Route Reply, intermediate CHs will calculate the hop-by-hop route according to the information contained in the list cluster addresses and put it in the calculated route field. The CHs will also store the calculated positions in the LT. The CHs use this location information to form the request area in the future to perform limited flooding which helps to reduce the overall propagation of control packets.

When the source node has information about the destination location, limited flooding is applied. The CH of the source forms the request area. The CH divides the space into four areas as shown in Figure 5 (B). The RREQ in limited flooding contains the boundaries of the area that the source CH expects the destination to exist in.

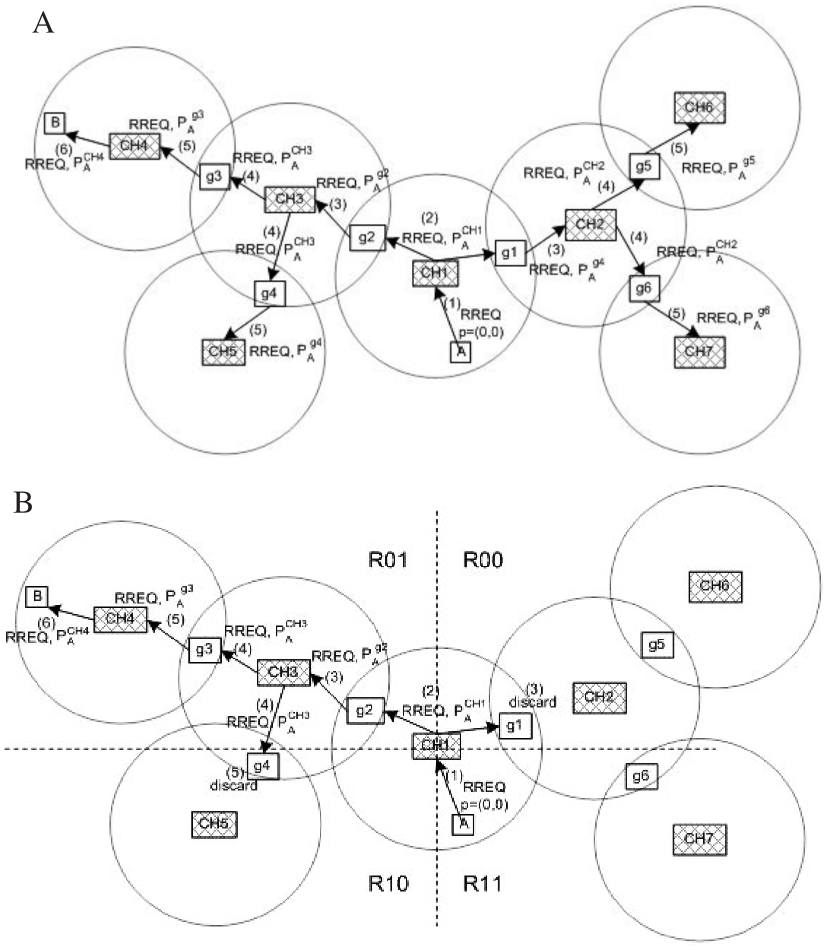


**Fig. 5. (A-B)**
**A.** Complete flooding for RREQ.
**B.** Limited flooding for RREQ.

The computation of relative positions along the path to B keeps the boundaries of the request area and prevents the RREQ from propagating outside it. Initially, the CH floods the RREQ in all the areas for two hop radius. If the destination is not found, then only the request area indicated by the destination's position is flooded. If the destination is not found in its corresponding request area, the CH floods the adjacent request areas and so on till it finds the destination. If the destination is not fond then the CH delete its entry from the LT.

In Figure 5 (B) assume the existing location information about B states that B is in request area R01. Then the x component of the calculated position must always be negative while the y component must be positive. If the calculated position at some CH or GW violates these two conditions, then this CH or GW is outside the request area and therefore it simply discards the RREQ message. If the destination B is not found in the request area R01, then it is most probably that B has moved either to area R00 or R10. Then limited flooding is initiated in both these areas. In area R00 both x and y components have to be positive while in area R10 both components have to be negative. If B is not found in neither R00 nor R10, then B is searched in area R11 where x component should be positive and y component has to be negative. If B is not found then it is inaccessible and a route con not be established to it.

### *Actual Packet Routing*

When the source CH obtains the route to the destination it sends data through this route. When a forwarding node finds out that the next hop along the source route is no longer reachable, it will create a route error (ERR) packet and send it back to the source to notify it of the link failure. Then the source will perform limited flooding to repair this error.

## SIMULATION RESULTS

The performance of the jobs-distribution solution is evaluated via simulations using JIST-SWANs simulator (Barr, 2004; Barr 2005). The simulation attempts to compare the performance of LECBRP, CBRP, AODV, LEOD protocols. Our evaluation is based on the simulation of 200 mobile nodes in 2000*2000 square meters. Random way point mobility model is used in our experiments with pause time of 30s (Navidi and Camp, 2004). In this model, a node travels towards a randomly selected destination in the network. After the node arrives, it pauses for the predetermined pause time and travels towards another selected destination. The data traffic simulated is constant bit rate (CBR) (Perkins, 2001) traffic. 30% of nodes, CBR sources, generate 128-byte data packets every (20-25) second. The simulation counts the number of control packets propagated during the 9,000 sec. and the number of the overall packets then calculates the overhead percentage by equation 3.

$$\text{overhead percentage} = \frac{\text{number of control packets}}{\text{total packets}}$$

Simulation results show that LECBRP outperforms CBRP, AODV, and LEOD protocols. Figure (6) shows control overhead percentage during 9,000 sec. The control overhead in LECBRP is also much smaller than CBRP, LEOD, and AODV. Figure (7) shows the impact of speed on control overhead percentage during 9,000 sec. The control overhead in LECBRP is much smaller than CBRP, LEOD, and AODV. The control overhead in LECBRP decreases with simulation time. Generally, the control overhead increases when the network becomes highly dynamic because nodes join and leave clusters quickly which causes cluster memberships updates i.e. control packets are flooded in the network. Figure (8) shows control overhead percentage during 9,000 sec. for 50, 100, 150, 200, 250, 300 nodes. The control overhead increases when the network is dense. However, the control overhead in LECBRP is much smaller than CBRP, LEOD, and AODV.

## CONCLUSION AND FUTURE WORK

In this paper we presented a novel cluster-based location enhanced routing protocol, the LECBRP. LECBRP provides the advantages of both clustering and local positioning. As a cluster-based protocol, LECBRP provides a structure for Ad hoc networks which makes it more scalable. Both clustering and location estimation helped to reduce the control overhead. Simulations show

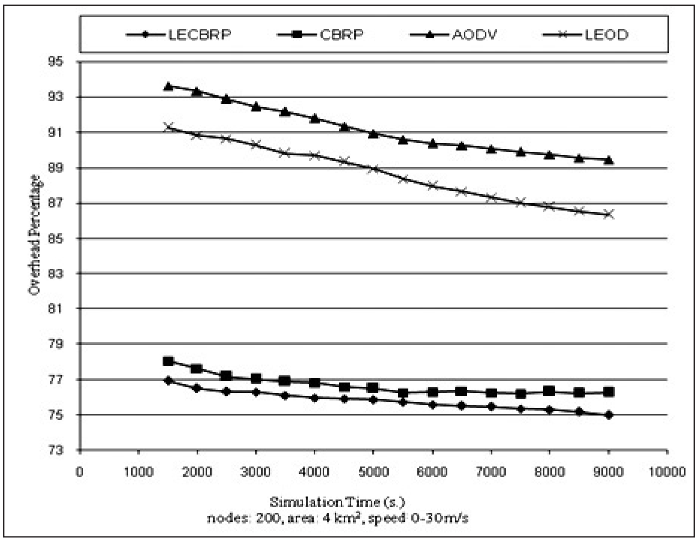


**Fig. 6.** Control overhead vs. simulation time.

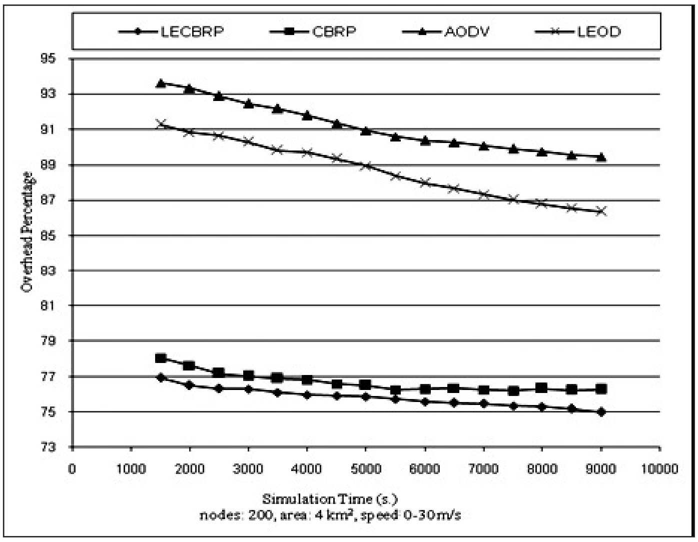


**Fig. 7.** Control overhead vs. speed.

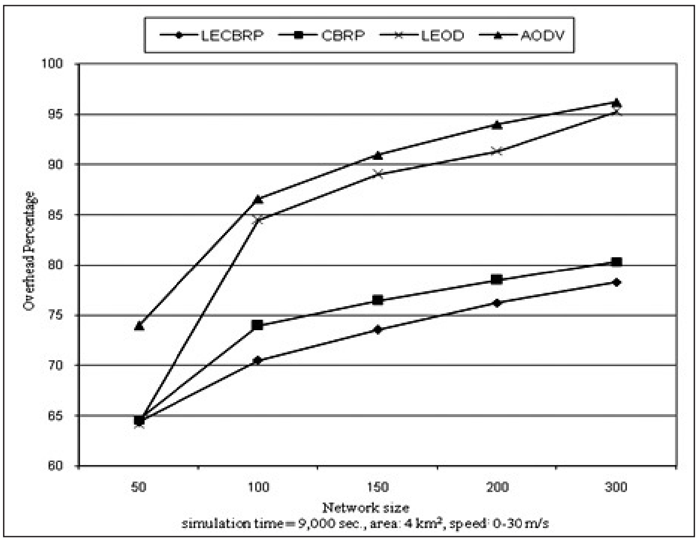


**Fig. 8.** Control overhead vs. network size.

that this novel protocol improves the performance of Ad hoc networks.

For simplicity, we proposed that the CH divides the space into four areas in order to form the request area. Our future work will be to develop a mechanism to dynamically determine how to divides the space around the CH based on the service to mobility ratio.

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Rec. 08/06/2008.
In-revised form: 09/09/2009