行政院國家科學委員會專題研究計畫　成果報告

子計畫二：具位置知覺之無線隨意行動網路的繞徑協定

計畫類別：整合型計畫
計畫編號：NSC91-2213-E-009-073-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
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計畫主持人：曾煜棋

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中　華　民　國 92 年 9 月 26 日

行政院國家科學委員會補助專題研究計畫成果報告

具位置知覺之無線隨意行動網路的設計與實作
子計畫二：具位置知覺之無線隨意行動網路的繞徑協定

Design & Implement Location-Aware of Mobile Ad Hoc Networks
Sub-Project(2): Location-Aware Routing Protocols for Mobile Ad Hoc Networks

計畫類別：□個別型計畫　　■ 整合型計畫
計畫編號：NSC 91－2213－E009－073
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計畫主持人： 曾煜棋 教授

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摘要：

行動隨意網路(MANET)是一個包含一些可以互相通訊的移動節點而不需要藉由基地台的協助就可以通訊的無線網路。Geocasting 是對於位於特定的地理資訊的一群節點做資料傳播。位於特定區域內的接收者可以收到來源端發出的訊息。在本篇文章中，我們提出一個新的 geocasting 協定，試著採用地理資訊來協助將資料傳遞到目的區域。模擬實驗的結果顯示我們的方法可以減少網路流量的負荷並獲得較高的資料到達速率。

關鍵字：geocast，全球定位系統，位置感知，行動隨意網路，行動計算，無線通訊

Abstract

A mobile ad hoc network (MANET) is one consisting of a set of mobile hosts capable of communicating with each other without the assistance of base stations. Geocasting is that a group consists of the set of all nodes within a specified geographical region. Hosts within the specified region can receive the message from a source node. In this paper, we propose a new geocasting protocol, which tries to exploit location information in delivering data packet to destination region. Simulation results show that our geocasting protocols can reduce the overhead of the network traffic and get high probability of data arrival rate.

Keywords: geocast, GPS, location-aware. mobile ad hoc network(MANET), mobile computing, wireless communication

1 Introduction

A mobile ad hoc network (MANET) is one consisting of a set of mobile hosts which can communicate with one another and roam around at their will. No base stations are supported in such an environment. When an application must send the same information to more than one destination, multicasting is often used, because it is much more advantage than multiple unicasts in terms of the communication costs.

To do multicast, some ways are needed to defined multicast groups. In conventional multicasting algorithms, a multicast group is considered as a collection of hosts which register to that group. It means that, if a host wants to send a message to such a group, they simply multicast it to the address of that group. All the group members then receive the message. However, another approach is so called geocasting. A geocast is delivered to the set of nodes within a specified geographical area. Unlike the traditional multicast schemes, the multicast group is implicitly defined as the set of nodes within a specified area.

This paper investigates the geocasting problem in a MANET by exploiting the location information of mobile hosts. In our geocasting protocol, we treat the geographic area as a number of logical grids, each as a square. In each grid, one mobile host (if any) will be elected as the leader of the grid. Geocast protocol is then performed in a grid-by-grid manner through grid leaders. In wireless environment, the broadcast can easily lead to a storm effect causing serious redundancy, contention, and collision [1]. Our geocasting protocol not only reduces the overhead of flooding, but also can increase the arrival rate of data packet. The basic assumption in location-aware geocasting protocols is the availability of a positioning device such as a Global Positioning System (GPS) receiver at each mobile host [2].

2 Background and Motivation

A. Review of Geocasting Protocols

The first proposed geocasting problem is in [3]. In their scheme, multicast group members are defined as all nodes within a certain region. To support location-dependent services, they suggested three methods: geo-routing with location aware routers, geo-multicasting modifying IP multicast, and an application layer solution using extended Domain Name Service (DNS). In [4], they proposed a geocasting scheme in MANETs. Their scheme is based on a multicast flooding approach. They try to utilize location information to limit the search space for decreasing overhead of data delivery. They define the forwarding zone to be the smallest rectangle that includes current location of sender and multicast region, such that the sides of the rectangle are parallel to the X and Y axes. The sender node can thus determine the four corners of the forwarding zone. The sender node includes the coordinates of the forwarding zone in a multicast packet when initiating the multicast delivery. When a node receives the multicast packet, it simply discards the packet if the node is not within the rectangle specified by the four corners included in the packet.

B. Observation and Motivation

In [4], they only tries to use the location information to confine the forwarding zone to reduce the overhead of delivering the multicast packet. However, their flooding scheme will result some problems using broadcasting in MANET environment. It is worth pointing out the result shown in[1], that such a broadcast can easily lead to a storm effect causing serious redundancy, contention, and collision. First, because the radio propagation is omnidirectional and a physical location may be covered by the transmission ranges of several hosts, many rebroadcasts are considered to be redundant. Second, heavy contention could exist because rebroadcasting hosts are probably close to each other. Third, collisions are more likely to occur because the RTS/CTS dialogue is inapplicable and the timing of rebroadcasts is highly correlated. Collectively, these problems are called the broadcast storm problem [1].

Existing multicast protocols [5][6] based on multicast tree-based approach may not work well in mobile ad hoc networks as dynamic movement of nodes. To motivate our work, we do not adapt the multicast tree-based approach. If we can overcome the problems of the overhead of delivering packets and broadcast storm, the multicast flooding scheme will be good scheme. In Section III, we will propose a geocast protocol.

3 The GRID Geocasting Protocol

A. Protocol Overview

Our protocol is called GeoGRID. The geographic area of the MANET is partitioned into 2D logical grids. Each grid is a square of size $d \times d$. Grids are numbered (x,y) following the conventional xy-coordinate. Each host still has a unique ID (such as IP address). To be location-aware, each mobile host is equipped with a positioning device such as a GPS receiver from which it can read its current location. Given any physical location, there should be a predefined mapping from the location to its grid coordinate. In each grid, one host will be elected as the gateway of the grid. The responsibility of gateway hosts is to propagate data packets to neighboring grids.

One thing which is unspecified above, but will affect the performance of our protocol, is d (the side length of grids). Let r be the transmission distance of a radio signal. We discuss six possibilities of choose d:

1. d is too large: The radio signal of a gateway host will have difficulty in reaching places outside of the grid, and thus a gateway-to-gateway communication is unlikely to succeed. So a d which is too large is unrealistic. (See Fig. 1(a), which shows the case of d=2r.)

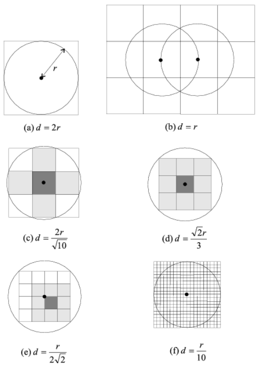


Fig.1. The relation between d and r

2. $d = r$: This represents the maximum value of d such that the gateways of two neighboring grids can talk to each other if they are located precisely at the centers of grids. (See Fig. 1(b).)

3. $d = \frac{2r}{\sqrt{10}}$: This represents the maximum value of d such that a gateway located at the center of a grid is capable of talking to any gateway of its 4 neighboring grids. (See Fig. 1(c).)

4. $d = \frac{\sqrt{2}r}{3}$: This represents the maximum value of d such that a gateway located at the center of a grid is capable of talking to any gateway of its 8 neighboring grids. (See Fig. 1(d).)

5. $d = \frac{r}{2\sqrt{2}}$: This represents the maximum value of d such that a gateway located at any position of a grid is capable of talking to any gateway of its 8 neighboring grids. (See Fig. 1(e).)

6. d is too small: This means that there will be very few, or sometimes no, mobile hosts resident in a grid. The chance of a mobile host becoming a gateway is high. In the extreme case, when d is infinitely small, there will be infinitely many grid and each host is the gateway of its own grid.

The above discussion implies that a smaller value of d will lead to higher connectivity between neighboring grids. However, a smaller d also means more number of leaders in the network, which in turn implies a higher overhead of delivering packet and more broadcast storm. So there exist some tradeoffs in choosing a good value of d.

B. GRID Geocasting Protocol

The main features of our GeoGRID are as follows. First, we will use the locations of source and geocast region to confine the forwarding range. Second, instead of letting every host to forward data, we only allow gateway hosts to take this responsibility. In this paper, two versions of GeoGRID will be proposed, one called flooding-based and the other called ticket-based.

In the flooding-based approach, no spanning tree or routing path will be established prior to geocasting. Each node serving as a grid gateway within the flooding region will help forwarding geocast messages. All other hosts will not do so. Note that this is different from pure flooding, although the approach carries a name "flood".

When a node *S* wants to send a geocast message to a destination region *G*, a packet *DATA*(*S*, *id*, *G*, *R*) will be sent, where

- *id*: the identification (or sequence number) of geocast message.
- *R*: the minimum rectangle that covers the grids of *S* and *G* (see Fig. 2 for an illustration). We call *R* the flooding region.

When a host *X* receives such a data packet, the following actions will be taken:

1. If *X*'s current location is outside of *R*, it will discard the packet.
2. If X is a gateway and its current location is within R, it uses the tuple (S, id) to detect if this is a new packet (this is to avoid endless flooding of the same packet). If so, X will rebroadcast this packet; otherwise, it discards this packet.
3. If X is within the geocast destination G, it forwards this packet to the upper layer; otherwise, it discards this packet.

For example, in Fig. 2, hosts *A, B, C, D, E, F, H*, and I are the gateways of grids (1, 1), (2, 1), (2, 0), (3, 2), (3, 1), (4, 1), (2, 2), and (0, 1), respectively. Suppose host *S* initiates a geocast to the region *G* bounded by grids (3, 2), (5, 2), (5, 3), and (3, 3). Then the flooding region *R* will be the rectangle bounded by grids (1, 0), (5, 0), (5, 3), and (1, 3). When host *B* receives this packet for the first time, since it is within the flooding range, it will rebroadcast this packet. This is the same when E receives this packet. However, when host I receives this packet, it will ignore the packet as it is not within R. Finally, as *D* receives the packet, it will forward the packet to all other gateways in *G*, hoping to deliver the geocast message to all other hosts in *G*.

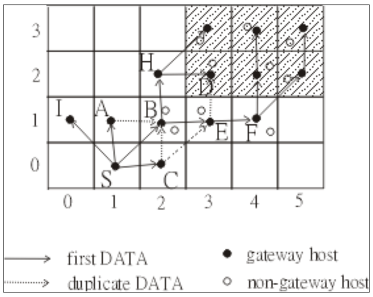


Fig. 2. example of flooding-based GeoGRID

In the ticket-based approach, geocast messages are still forwarded by gateway hosts, but not all the gateways in the flooding region will do this job. The concept is to avoid blind flooding, we will issue a number of tickets, each responsible of carrying one geocast message to the destination region. A geocasat message will be denoted by *DATA*(*S*, *id*, *G*, *R*, *n1*, *t1*, *n2*, *t2*, *n3*, *t3*), where

- *S*: the source host.
- *id*: the identification of geocast message.
- *G*: the geocast region.
- *R*: the minimum rectangle that covers the grids of *S* and *G.*
- *n1, n2,* and *n3*: three grids that are within the flooding region, are neighboring to the grid of the current sending host, and are closer to the destination region than the current sending host. Note that it is possible that there are less than three grids satisfying these conditions. If so, we simply fill these fields by ∅.
- *t1, t2,* and *t3:* the numbers of the tickets issued to *n1, n2,* and *n3,* respectively.

Observe that the number of tickets issued by the source node will proportionally reflect the geocasting overhead, but will affect the arrival rate of the geocast messages. In this paper, we propose to set up this value proportional to the size of the destination region. Specifically, assuming that the destination region is a rectangle of $m \times n$ grids, we will issue $m + n$ tickets from the source node. On a relaying host receiving k tickets, it will evenly divide these tickets to its neighboring grids that can satisfy the aforementioned conditions.

Now, suppose a gateway host *X* within the flooding region *R* receives a geocast packet containing *k* tickets for it. The following rules will be used.

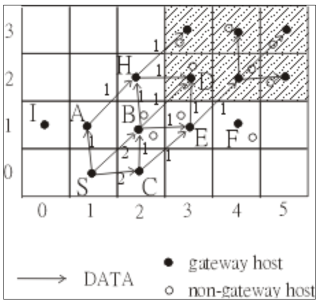


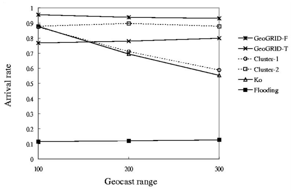
Fig. 3 example of ticket-based GeoGRID

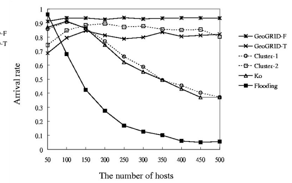
- *X* is not within *G: X* will select from its neighboring grids that are closer to the destination region *G* and are within the flooding region *R.* Then *X* will forward (through broadcasting) the geocast message by evenly distributing its *k* tickets to these neighbors. Note that if this geocast message is a duplicate message but from a different neighboring grid, *X* will not discard this packet. Instead, *X* will still follow the above rule to forward the geocast message. This is to follow our original philosophy that each ticket is responsible of carrying one copy of the geocast message to the destination region.
- *X* is within *G:* Since the geocast packet has arrived at the destination region, *X* will always rebroadcast the packet (in hope of achieving a higher arrival rate).

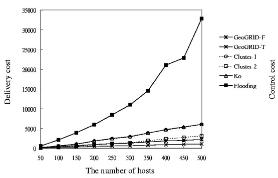
An example is shown in Fig. 3. Five tickets are issued by the source host S with a geocast packet *DATA*(*S*, *id*, *G*, *R*, (2, 0), 2, (2, 1), 2, (1, 1), 1). On the gateway host *C* receiving this packet, it may broadcast a packet *DATA*(*S*, *id*, *G*, *R*, (2, 1), 1, (3, 1), 1, (3, 0), 0). For gateway host B, it may broadcast a packet *DATA*(*S*, *id*, *G*, *R*, (2, 2), 1, (3, 2), 1, (3, 1), 0). After a while, when *B* receives *C*'s packet, since there is a ticket for it, it has to rebroadcast the geocast message. Based on a round-robin rule, B may broadcast a packet *DATA*(*S*, *id*, *G*, *R*, (2, 2), 0, (3, 2), 0, (3, 1), 1). On any gateway host within the destination region *G* (such as *D*) receiving the geocast packet for the first time, it should rebroadcast the packet.

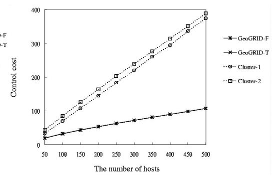
4 Experimental results

In the following, we will compare the arrival rate of geocast, the delivering packet cost, and control packet cost. The arrival rate is calculated as ratio of the number of geocastgroup member, which actually receive the geocast packets, and the number of group members, which were supposed to receive the packet.









5 Conclusions

In this paper, we have presented a new location-aware geocasting protocol for MANETs. We have shown how to utilize location information to assist geocast problem in a MANET. The protocol is characterized by two interesting features. First, it offers a much less routing cost than those of the existing protocols. This is achieved by confining the route searched zone to a limited area and by delegating the delivering data packet responsibility to one mobile in a grid area. Second, it offers much higher arrival rate of delivering packet. Since our protocol tries to delivering packets in a grid-by-grid manner, it can reduce the broadcast storm problem. Simulation results do justify these benefits.

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