# Obstacle-Free Geocasting Protocol for Ad Hoc Wireless Networks

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***Abstract*—Mobile Ad Hoc networks (MANET) comprise mobile hosts in a network bereft of base stations and characterized by a highly dynamic network topology. The MANET environment contains unpredictable obstacles, such as mountains, lakes, buildings, or regions without any hosts, impeding or blocking message relay. This study proposes geocasting protocol for sending short message from a source host to a geocasting region in Ad Hoc networks. The proposed protocol keeps messages away from unpredictable obstacles and creates a small flooding region. Experimental results show that a source host can send a short message to all hosts located in geographical area with a high success rate and low flooding overhead.**

***Keywords-Geocasting; short message; Ad Hoc network; obstacle; flooding overhead; Cellular-Based Management;***

## I. INTRODUCTION

An Ad Hoc network consisting of mobile hosts provides low cost and highly mobile communications. In contrast to a static network, Ad Hoc networks have no infrastructure, with each mobile host acting as a router, relaying information from one neighbor to others. Packet flooding is extensively used to establish a routing path from the source host to the destination. By considering all possible paths linking the source and destination, the source host can ascertain the shortest communication path. Ni [5] presented the problem of broadcasting storms and revealed the negative effects of the flooding operation. Various cluster-based protocols [3][6][7][8][13] have been developed to alleviate flooding, with the host in each partitioned cluster voting for a header to manage the cluster. Hosts wishing to establish communication paths should first send a request packet to their cluster manager, and the manager will then relay the packet to neighboring managers through manager-based flooding until the manager of the destination host is found. Cluster based protocols thus alleviate flooding, but increase management overheads.

Some other location-aware protocols [1][2] use GPS (Global Positioning System) to provide location information for establishing a routing path. The MANET is geographically partitioned into several disjoint and equally sized cell regions. The host can then use GPS to identify which grid it is located in. Within each cell, the host located closest to the center of the cell is selected as a manager, and handles the information of all the other hosts located in that cell. The manager is responsible for exchanging information or communications with managers of neighboring grids. When a source host wishes to establish a routing path to a destination host located in a different cell, the source host first issues a request to its manager. The routing path is then constructed by executing the manager-level flooding operation. In [12], the authors compare grid, triangular, and hexagon shapes and illustrate that cellular-based partition schemes generate fewer flooding packets during path construction. To alleviate flooding, the geocasting protocol proposed herein is developed based on the management model proposed in [12].

Different from unicast or multicast service, geocasting service is defined by sending messages from the source to all hosts located in a specific geographical region. Previous works [9][10][11][14][15], assumed that each host is equipped with a GPS that can determine its geographical position. Meanwhile, the source host is capable of defining a specific geocasting region and all hosts located in this region are considered to be receivers. Ad hoc networks, contain unpredictable obstacles, such as mountains, lakes, buildings, or subregion without any host. These obstacles will impede or block message relay. Message flooding from source to the geocasting region is a simple method of overcoming them. However, message spread from the source host to the geocasting region is very costly, and creates serious redundancy, contention, and collision[5]. In [11], Y. B. Ko proposed a LBM method for solving the geocasting problem. According to the source host location and geocasting region, a sender defines a forwarding zone and attempts to flood the message in the forwarding zone. If no obstacles exist, the message can be successfully flooded to all host in the geocasting region. However, if the estimated forwarding zone can't cover the obstacle, the message will be

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blocked. In this situation, Ko used a variable δ to enlarge the forwarding zone so that it can cover the obstacle. A large δ value results in a large forwarding zone, thus achieving a high success rate, but also causing contention, collision, and so on. As shown in Fig. 1, when the variable δ is zero, the forwarding zone does not cover the obstacle. Assuming that the value of variable δ is *K*, then the forwarding zone can cover all obstacles and the message can be transmitted to the geocasting region. The performance of geocasting service depends on the value of δ, which is unknown and is defined through trial-and-error. To overcome unpredictable obstacles, setting δ as a large value achieves a high success rate but creates many flooding packets in MANET. In [14][16], a Tora protocol is proposed to construct multiple paths from the source to a specific destination. Although the path constructed by TORA can be automatically recovered, packets are flooded over all MANET regions.

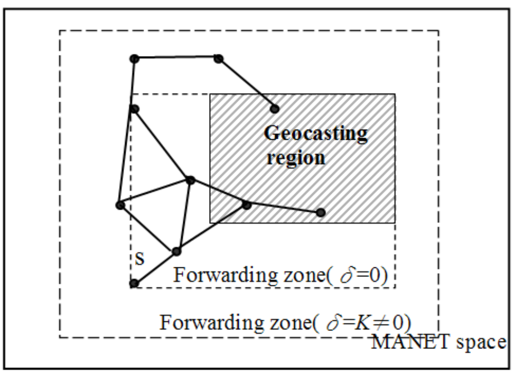


Figure 1. Execution of Location-based geocasting protocol[11].

This study focuses mainly on how to deviate from the unpredictable obstacle regions and create a small flooding region so that the message can be successfully relayed from source host to all hosts in a geocasting region. A OFGP(Obstacle-Free Geocasting Protocol) for MANET is proposed herein, which keeps messages away from obstacles by creating a very small flooding region. Even in cases involving unpredictable obstacles, OFGP relays the message from the source host to all hosts in a geocasting region with a high success rate and low flooding cost. Simulations are also conducted to measure the performance in terms of success rate, number of flooding packets, and the flooding regions in geocasting protocol. Experimental results demonstrate that the proposed protocol transmits the message from source host to the geocasting region at low cost and with a high success rate.

The rest of this investigation is organized as follow. Section 2 reviews the partitioning scheme of previous research. Protocol OFGP and examples for executing OFGP are presented in Section 3. Section 4 evaluates the performance of OFGP in comparison with previous works. Conclusions and suggestions for future works are finally presented in Section 5.

## II. Partitioning of the MANET Environment

The obstacle-free geocasting protocol proposed herein is based on the Cellular-Based Management model proposed in [12]. Cellular-Based Management geographically partitions the MANET into several disjoint and equally sized cellular, as displayed in Fig. 2. Each cell then is assigned a unique Cell-ID, as shown in Fig. 2. GPS, allows the host to identify which cell it is located in, and in each cell, the host located closest to the center of the cell will be selected as a manager for executing information exchange. The manager of each cell is assumed to be capable of communicating directly with the managers of neighboring cells. Each manager will periodically broadcast an "existence" message so that the neighboring managers know its existence. If a manager does not receive the "existence" message for a long time, it will mark the neighboring cell as an obstacle cell and record the information in its table.

The manager of a cell zone is replaced if the manager enters a new cell zone. Meanwhile, each host in a cell should record the ID of that region's manager so that they can relay requests to the manager whenever they need to communicate with other hosts. The manager should periodically broadcast a specific packet to notify members of the cell it is located in and notify neighboring manager of its presence. A new manager must be sought if the current manager suffers a fault or suddenly loses power. If a certain time elapses without any MANAGER packet being received, member hosts will repeat the manager selection process. A cell without manager is defined as an obstacle cell and each manager records the cell-ID of neighboring obstacle cell.

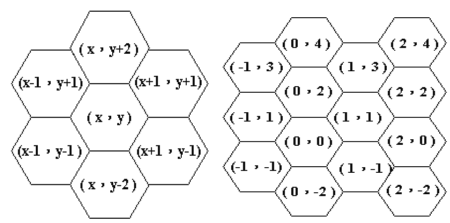


Figure 2. Cell-ID of a partitioned MANET.

The next subsection introduces the obstacle-free geocasting protocol that helps the source host to send a short message to all hosts in the geocasting region by executing few flooding operations and thus overcoming unpredictable obstacles.

## III. Obstacle-Free Geocasting Protocol (OFGP)

This section presents the Obstacle-Free Geocasting Protocol (OFGP). The OFGP mainly consists of two phases, the *reaching phase* and the *broadcasting phase*. In the *reaching phase*, the source host attempts to send the message to one host in the geocasting region. To keep away from the obstacles, the short message is flooded in a small region to ensure that the message can be sent to one host located in the geocasting region. During this phase, the size of the flooding region is dynamically convergent, following the shape of the obstacles. During the second phase, an attempt is made to broadcast to all hosts in the geocasting region. Since the geocasting region may contains some obstacle regions, messages sent by the host located in geocasting region may be blocked. During the broadcast phase, message will be sent to all hosts located in geocasting region, regardless of the presence of unpredictable obstacles. The following first introduces the reaching phase protocol, then describes operations of the broadcasting phase.

## A. Reaching Phase of OFGP

The OFGP comprises two phases, the *reaching phase* and the *broadcasting phase*. During the *reaching phase*, the source host tries to send the message to one host in the geocasting region. The source host first identifies the geocasting region and then evaluates the center location of the geocasting region. Let $C_s$ denote the cell-ID of the cell located by the source host, and let $C_d$ denote the cell-ID of the center of the geocasting region. The shaded region in Fig. 3 indicates the geocasting region. In the reaching phase, the cell $C_d$ is considered to be the destination. Managers that receive the short message will attempt to relay the message to the cell $C_d$.

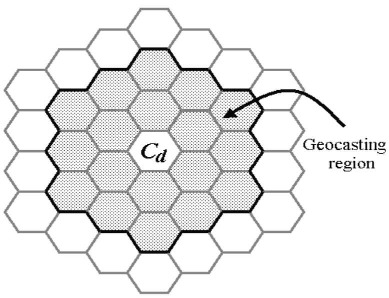


Figure 3. Center location of the geocasting region.

To describe the reaching phase protocol, the *promising cells* and *managers* are defined. The *promising cells* of a cell are the three neighboring cells that are closest to the geocasting region $C_d$. Managers of the promising cells are called *promising managers*. The direction $Dir_i$ that links the current cell and the promising cell is called *promising direction*. Fig. 4 illustrates the promising cells that have been numbered. A reaching phase protocol can efficiently keep the short message away from obstacle and successfully relay the message to some hosts of geocasting region. Examples for executing the reaching phase protocol are provided later.

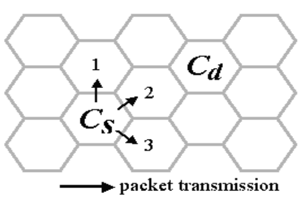


Figure 4. An example of promising cell of $C_s$.

A manager, say *M*, that is not located in the geocasting region and receives the short message packet will handle the received message by the following *reaching phase rules*.

*Rule 1*: Manager *M* should relay the message to the promising managers.

*Rule 2*: If manager *M* receives an already received packet, it will not relay or broadcast the message again. If the three promising cells are obstacles, manager *M* should relay the message to the other three neighboring managers.

*Rule 3*: If Rules 1 and 2 fail, the message will be returned to the neighboring manager who sent the short message to manager *M*.

The following uses an example to illustrate how the short message can overcome the obstacles by executing the *reaching phase rules*. As shown in Fig. 5, the black cells denote the obstacles, $C_s$ represents the ID of cellular the sender located, and $C_d$ denotes the central cell ID of the geocasting region. Executing the reaching phase rules creates a flooding region that is surrounded by black lines, as shown in Fig. 5. The numbers marked in each cell denote the packet flows.

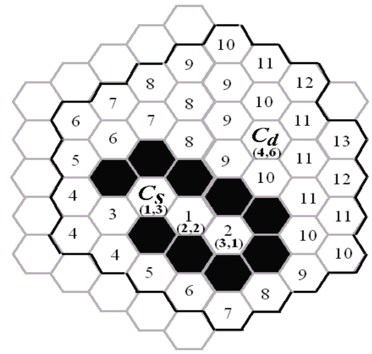


Figure 5. An example for executing reaching phase protocol in an obstacle environment.

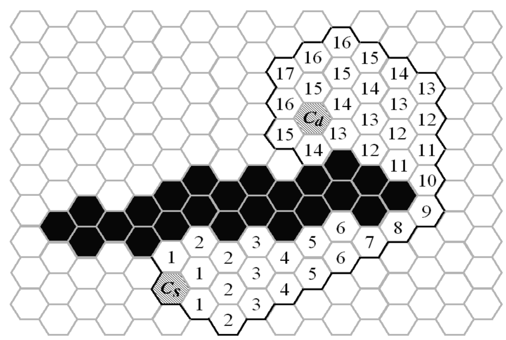


Figure 6. Special case of Line-shape obstacles.

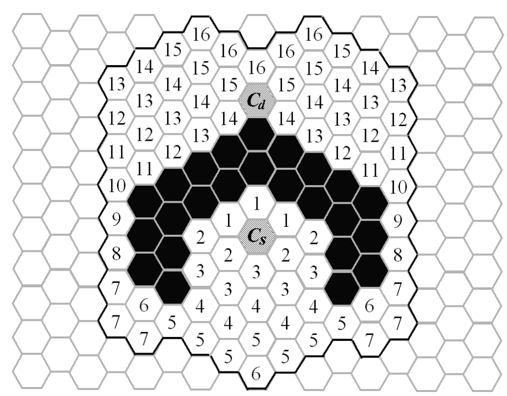


Figure 7. Special case of reverse-U-shape obstacles.

In Figs. 6 and 7, the black cells represent the obstacles, each flooded cell zone is numbered according to the order of packet flow. As displayed in Fig. 6, the short message transmitted from $C_s$ to $C_d$ is impeded by Line-shape obstacle. Applying the reaching phase protocol, allows the packet to be transmitted in a very small flooding area, so that it can overcome the obstacle and finally reach the geocasting region.

Meanwhile, the LBM geocasting protocol [11] creates a larger flooding area than the novel protocol, as shown in Fig. 8. Another case is when the $C_s$ surrounded by obstacles, as shown in Fig. 7. Short message packet also can be transmitted from $C_s$ to the geocasting region. Additionally, the flooding area can be convergent within a very small area, depending on the shape of obstacle. The efficiency of the novel protocol and previous approaches is shown in Section 4.

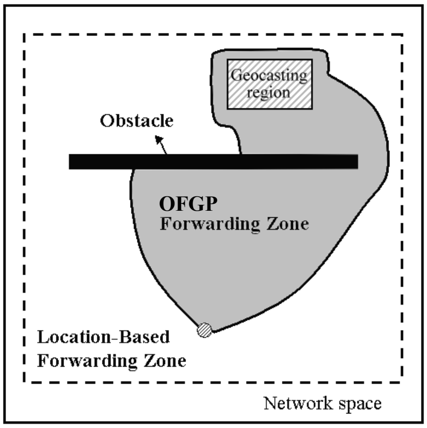


Figure 8. Comparison of flooding area of OFGP and LBM protocols.

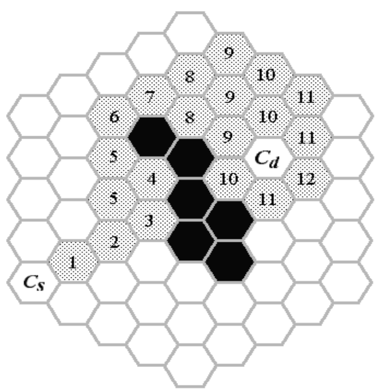


Figure 9. Execution of EOFRP

*B. Enhanced Obstacle-Free Reaching Phase Protocol (EOFRP)*

This subsection proposes an Enhanced Obstacle-Free Reaching Phase Protocol. The protocol proposed in this subsection reduces the size of flooding area before the presence of any obstacle. Rather than selecting the three promising managers, the current manager selects just one promising manager to which it then relays the packet. This approach reduces the size of the flooding area, as no obstacle exist in MANET. As soon as obstacles are encountered, manager applies the previously proposed *reaching phase protocol*, which selects three promising managers for overcoming the obstacles. Fig. 9 displays the operations of the *Enhanced Reaching Phase Protocol*.

To keep away from the obstacles, the short message is flooded in a small region to ensure the message can be sent to a single host located in the geocasting region. During the reaching phase, the size of the flooding region is dynamically convergent, according to the shape of the obstacles. As soon as the packet can be delivered to a manager in the geocasting region, managers perform the second phase protocol so that the packet can be transmitted to all managers in the geocasting region.

*C. Broadcasting Phase of OFGP*

This subsection describes the second phase protocol, the broadcasting phase protocol, for delivering packets to all hosts located in the defined geocasting region. Applying the reaching phase protocol, allows managers to relay the packet to a host in the geocasting region, even if the obstacles create difficulties. Let the manager of the cells surrounding the geocasting region be the *around manager*. Once the *around manager* receives the packet, it checks the field of destination cell ID, and executes the broadcasting protocol to help deliver the packet to all hosts in the geocasting region. While some obstacles may exist within geocasting region, we assume that no manager will be fully surrounded by obstacles and unable to communicate with any other manager. During the broadcasting phase, the geocasting region are treated as a large virtual obstacle region. Let $M_a$ denote the *around manager*, while $M_d$ represents the manager located in the geocasting region. Once $M_a$ or $M_d$ receive the "*forwarding*" packet, they initiate the following *broadcasting protocol*.

**Broadcasting Phase Protocol**

Rule 1: When $M_a$ receives packet, it treats the geocasting region as a large virtual obstacle. The manager $M_a$ makes two copies of the packet, one labeled "*forwarding*" and the other labeled "*around*". Similar to Rule 1 of *reaching phase* protocol, the manager $M_a$ selects three promising managers. Manager $M_a$ sends the "*forwarding*" packet to promising managers located in the geocasting region, and sends the "*around*" packet to other promising managers that are not located in the geocasting region.

Rule 2: If the three promising managers are located in the geocasting region, $M_a$ sends the "*around*" packet to the other three neighboring managers to ensure that the "*around*" packet could be transmitted around the geocasting region. Manager $M_a$ that applies Rule 2 of *Broadcasting Phase Protocol* treats the geocasting region as a virtual obstacle and applies the Rule 2 and Rule 3 of the *Reaching Phase Protocol.*

Rule 3: A manager $M_a$ that receives the "*around*" packet three times, or a manager that is neither $M_d$ nor $M_a$ will do nothing.

Rule 4: When manager $M_d$ receives the "*forwarding*" packet, it broadcasts to neighbors by flooding.

During the execution of broadcasting phase protocol, manager that is neither $M_a$ nor $M_d$ will do nothing. Fig. 10 illustrates the operation of the broadcasting phase protocol, where the black cells are geocasting region. When the *around manager* $M_a$ receives packet, it checks that itself is an *around manager* and prepares two types of packets, as illustrated by Rule 1 and Rule 2. Manager $M_a$ treats the whole geocasting region as a virtual obstacle, evaluates the three promising managers, and sends packets to cell indicated by an arrow. Two of the promising managers are located within the geocasting region and will receive the "*forwarding*" packet from $M_a$. Meanwhile, one of the promising managers which is located close to the geocasting region, will receive the "*around*" packet from $M_a$.

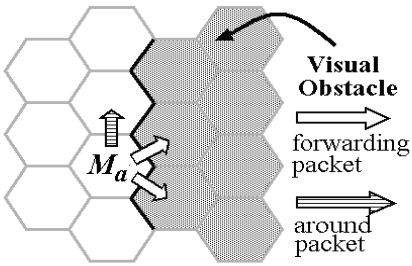


Figure 10. Operation of broadcasting phase protocol.

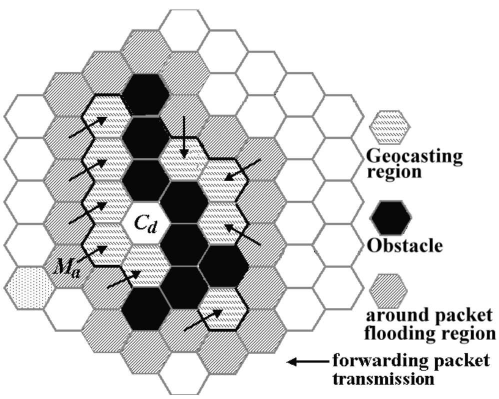


Figure 11. Operation of broadcasting phase protocol.

Once the "*forwarding*" packet has been delivered to the geocasting region, managers that are located in the geocasting region will receive the "*forwarding*" packet and broadcast the packet to all hosts in geocasting region. However, obstacles may exist in the geocasting region that blocks the packet transmission. Fig. 11 is a special case that blocks the flooding operation. To ensure that all hosts in the geocasting region will successfully receive the packet, the proposed broadcasting phase protocol uses the "*around*" packet to increase the opportunities for transmitting the packet into the blocked region. The *around manager* $M_a$ treats the geocasting region as a virtual obstacle and applies the Rule1 and Rule 2 of broadcasting phase so that the "*around*" packet can be transmitted along the geocasting region. Consequently, the packet can be transmitted to all hosts located in the geocasting region with a high success rate. Fig. 11 displays the execution of the broadcasting phase protocol.

## IV. PERFORMANCE STUDY

The previous section proposed OFGP protocol for sending short message from a single source host to geocasting region. By applying the proposed protocol, the manager of each cell transmits the short message packet to create a small and convergent flooding region, and keeping the packet away from various obstacles. This section proposes the performance investigation of the OFGP protocol.

The size of the MANET region is 1600*1600 units, while the radio transmission range of a host is set at a constant 100 units. To partition the MANET into several cells, the cell length is set at $100/\sqrt{3}$. In the MANET environment, the performance of the LBM[11], OFGP, EOFGP protocols is examined first. The EOFGP protocol is the same as the OFGP protocol, except that the *Enhanced Reaching Phase Protocol* is adopted rather than *Reaching Phase Protocol* of OFGP. Performance measures considered herein include traffic overheads caused by flooding, the success rate in transmitting short message to all hosts in a geocasting region, and the time costs in transmitting short message packet to the geocasting region. The number of hosts varies, including 1000, 1250, 1500, 1750, and 2000, and their locations are randomly determined. The $\delta$ value of LBM is set at 50 units.

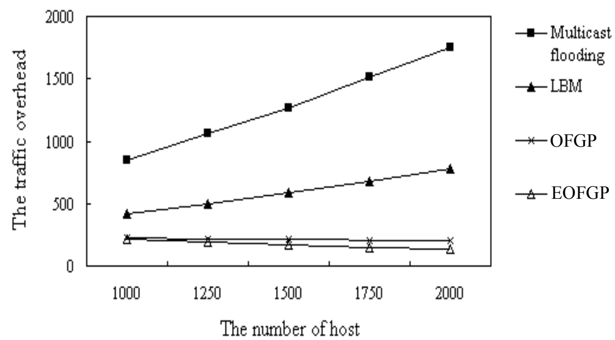


Figure 12. Comparison of traffic overhead

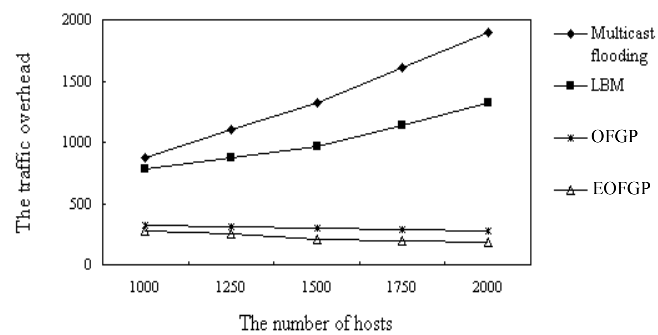


Figure 13. Comparison of traffic overhead for geocasting protocols. The reverse-U-shape and Line-shape geographical obstacles are introduced.

Figs. 12 and 13 compares the traffic overheads of the LBM, OFGP, EOFGP and Multicast flooding protocols. Using the Multicast flooding and LBM protocols, each host transmits the short message packet hop by hop until the packet has been delivered to the geocasting region. Thus, the traffic overhead is proportional to the number of hosts. However, in the proposed OFGP and EOFGP protocols, the MANET is partitioned into a fixed-size cell and only the managers of each cell participate the packet transmission. Traffic overheads thus do not increase with the number of hosts. The number of cells without managers decreases with an increasing number of hosts, thus decreasing the number of obstacles. Consequently, the traffic overheads involved in keeping the short message away from the obstacles are saved. If the neighboring region is not an obstacle, managers that apply the EOFGP protocol only transmits packet to the most promising manager, instead of transmitting packet to the three neighboring managers. An increasing number of hosts means fewer cells contain obstacles and thus reduce the traffic overheads for transmitting a packet to three neighboring managers. This phenomenon is significant as found in EOFGP.

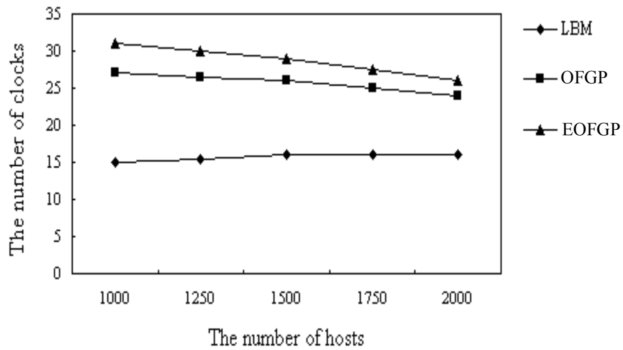


Figure 14. Time cost for geocasting protocols.

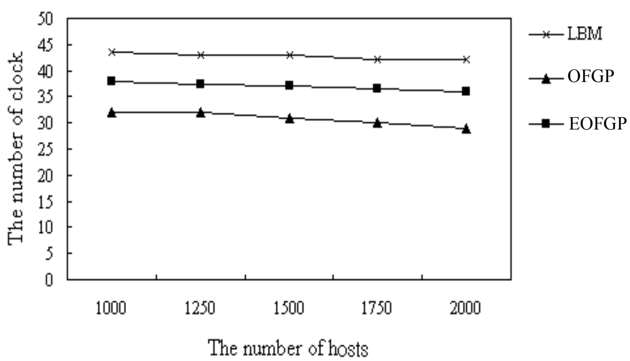


Figure 15. Time cost for geocasting protocols. The reverse-U-shape and line-shape obstacles are introduced.

Figs. 14 and 15 compare the time costs of the LBM, OFGP, and EOFGP protocols. Notably, in Fig. 14, obstacles are formed because some cells lack a host. Since the obstacles are mostly small blocks, the LBM uses a flooding based mechanism to transmit packets, and thus achieves a smaller time cost than OFGP and EOFGP. Fig. 15 displays randomly generated the reverse-U-shape and Line-shape obstacles on MANET. Compared with OFGP and EOFGP, the time costs of LBM are increased significantly in Fig. 15. Since the initial $\delta$ value of LBM can not cover the geographical obstacles, a second flooding from source to geocasting region is the key reason for the increasing time cost.

## V. Conclusions

This study proposed a novel Obstacle-Free Geocasting Protocol for the geocasting problem. Compared to existing approaches, the novel protocol creates a smaller flooding area and achieves a higher success rate for relaying a packet to geocasting region. The protocol presented herein keeps the short-message packet away from the obstacles and creates the flooding area in a convergent manner. Simulation results demonstrate that the proposed protocol is obstacle-resistant and performance well in terms of success rate and flooding overheads.

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