A MANET Protocol for Information Gathering from Disaster Victims

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Abstract

In this paper, we propose and evaluate a MANET system to pursue the location and personal information of victims in disaster occurrence where we do not assume any fixed network infrastructures. Our proposing method gathers the information from victims' terminals with GPS receivers using ad-hoc communication through victims' terminals and vehicles. In our system, the disaster area is divided into grids and the data will be cooperatively held by the mobile terminals in each area. If the capacity to hold the data in an area is not enough, a part of the data will be relocated to neighbor areas. We have simulated our system in focus of information gathering rates and information keeping rates. Our experimental results show that the proposed system works effectively.

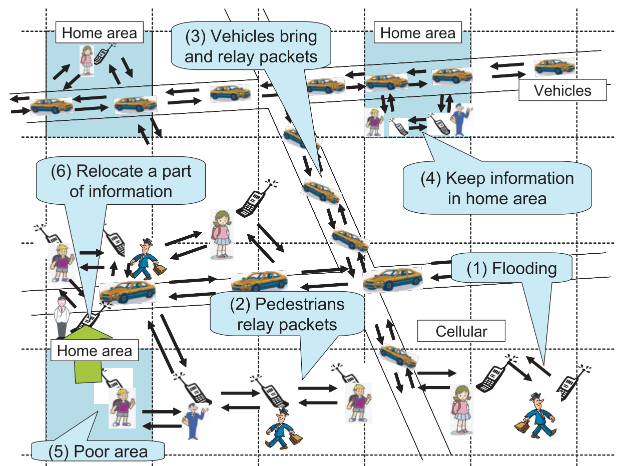

Figure 1. Overview of our system

1 Introduction

It is very important to prepare some information gathering systems for rescue operations from massive scaled terrorism or unpredictable natural disasters like as earthquakes, typhoons, eruptions of volcanoes and floods. Currently, the governments and companies providing public infrastructure prepare the hazard maps, which show the predication of the damage caused by major disasters such as damaged areas and victims' behavior in the areas. However an actual disaster may cause very large scale of damage and some victims may take unexpected actions in such a disaster. So it is very important to gather the correct information from disaster areas. But the widely constructed infrastructures like backbone networks of cellular phones can be damaged easily by disasters.

On the other hand, there is another requirement for knowing liveness and location information of ones' relations on disaster. In Japan, some services called disaster dial are provided and used on recent disasters, which are some kind of billboard systems for cellular phones. However in order to use such systems on disasters, we must solve some problems like how to avoid network congestion around the servers and how to ensure the network infrastructures.

For this purpose, we propose an ad-hoc network based protocol for collecting victims' locations and liveness information autonomously. In our protocol, we have assumed there are many high performance terminals such as 3G cellular phones and vehicular terminals and they can make an ad-hoc network among them. Recently, the cellular phones with GPS (Global Positioning System) receivers are provided and have been spreading. Also, some cellular phones have been

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Table 1. Type of nodes

	Handheld	Vehicular
Battery	finite	infinity
Memory	finite	infinity
GPS	equipped	equipped
Tras. Range	100m	200m
Move speed	Average 0.5m/sec	Average 5m/sec

becoming to equip wireless LAN modules such as IEEE802.11[5]. Among all the mobile devices, the vehicular terminals like car navigations systems are especially powerful. Since vehicles have rich battery source and can move more quickly than humans, they may collect much more information from much wider areas. Table 1 shows our assumption of terminals.

So, we have designed our system based on such devices. At first, we assume that the victims input their information into their own cellular phones about liveness, health, request for some help and so on. Each cellular phone automatically adds the location received from its own GPS module to its user's information and the information (called *registered information*) is sent to its owner's *home areas* by flooding (Fig. 1(1),(2),(3)). Here, we define one's home areas as the surrounding areas of his/her base positions such as one's house or one's office. A person can have multiple home areas redundantly and his/her registered information will be held by the terminals in the home areas cooperatively (Fig. 1(4)). If the number of the registered information in an area exceeds its capacity (of the terminals in the area), a part of the registered information will be relocated to its neighbor areas (Fig. 1(5),(6)). By this scheme, our system does not require any widespreaded public infrastructures. Also we can avoid overconcentration of the query access from victims' relations to check their liveness, and we make our system more scalable.

From some experiments, we show our system can gather and keep the registered information efficiently without using any infrastructures.

2 Related work

Due to limited battery resource, it is important to reduce power consumption for realizing ad-hoc networks among handheld terminals. In [1], an optimized route selection method to reduce power consumption is proposed, where the terminals search the best routes by changing transmission power levels step by step. In [8], a construction method of broadcast trees with least power consumption is proposed. In [14], authors direct their attention to the trade-off between power consumption and transmission speed. They propose a construction method of power-aware data aggregation trees that satisfy given constraints about node-to-node transmission time. These are aimed to the environments composed by non-movable nodes and there are other studies considering movable nodes[3, 13]. In these studies, they have proposed power-aware management methods of ad-hoc networks under the condition where the nodes may move and the topology may be also changed.

On the other hand, in [10], an identifying method of damaged areas on disaster is proposed, but this method aims to indoor sensor networks unlike our method aiming to wide disaster areas. Some studies for help of rescue operations are also done [6, 4]. But in these methods, nodes' mobility is not considered or considered only as the cause of topology change. In our method, we use the nodes' mobility much aggressively where we consider realistic mobility of victims and vehicles in urban areas[7, 9, 11].

It is well known that the performance of ad-hoc network protocols is affected by nodes' mobility models very much [2]. So we have evaluated our protocol by using some different mobility models.

3 MANET based distributed information management system on disasters

In our system, one victim's information is assumed to be represented as a tuple of ID, the number of cellular phone, the location of home positions (home, office etc.) and a short message. We also assume that each tuple can be encoded within 100 bytes.

Our system divides the whole area into grids. We assume that all the terminals know this division. Each divided area is a unit of data management and each person can specify multiple home areas among them in advance. All the victims' information will be sent to the area hop by hop to the home areas.

If an area has not enough capacity of data holding because of low density of terminals, a part of data will be reallocated to the neighbor areas.

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Table 2. Directed flooding protocol

```
Sender:
 Send Packet with sender's position
Receiver:
 If Message.Living_time > Cur_time()
  Then
   If Dist(Send.pos,Dest.pos)
      > Dist(Rec.pos,Dest.pos)
     Then Rebroadcast
     Else Rebroadcast in Probability p
   Else Discard
```

3.1 Directed flooding protocol

We have proposed a flooding based protocol for inter-vehicle communication called RMDP(Received Message Dependent Protocol)[11]. In RMDP, the transmission time interval is adjusted according to the number of received messages and detected collision errors in order to realize stable data exchange. But RMDP is designed for distribution of road information collected by vehicles without any direction. So we have modified RMDP for directed flooding.

As shown in Table 2, in this protocol, a messages is only relayed when the receiver is nearer to the destination than the sender. Here, *Send.pos*, *Rec.pos* and *Dest.pos* are the positions of the sender, receiver and destination (i.e. home areas), respectively. *Cur_time()* and *Dist(A,B)* are functions that returns the current time and distance between A and B, respectively. *Message.Living_time* is the time to live in which the packet can be transmitted and calculated as follows.

$$Living\_time = \frac{Dist(Src.pos, Home.pos)}{(trans\_range * 1/2)} \quad (1)$$

Src.pos, *Home.pos* and *trans_range* are the source position (where the victims send his/her information), the positions of the home areas and the given radio transmission range. At first, the victim's terminal V sends the information message. If some terminal H in his/her home area receives the information, H will return an ACK message back to V by using the above protocol in opposite direction. V will wait for an ACK message in three times as long as $Living\_time$. In the case that V cannot receive any ACK, V will send the message with doubled $Living\_time$ again.

Also we define *sleep mode* and *active mode* for handheld terminals. In sleep mode, the terminals cut off transmission power to reduce power consumption.

Table 3. Data relocation protocol

1. Start this relocation procedure if the delete count exceeds threshold A
2. Select a destination area of relocation
   - Collect the delete count of neighbor areas
   - Select the destination area that has the smallest average delete count smaller than threshold B
   - If there are no such an area, cancel relocation
3. Select data to relocate
   - Some data sets are selected by a hash function calculated from the time (i.e. a fixed sets are selected in a duration)
4. Send the selected data to the relocate area
5. Wait for ACK to ensure relocation
6. Send *delete messages* to the terminals in the area by flooding

3.2 Register and management of data

The data input by a victim will be sent to his/her home areas by using our directed flooding protocol. Each terminal receiving the data will check if it is in one of the home areas of the owner of the data. If it is out of the home areas, the data will be relayed according to the protocol. If it is in the home area, it returns an ACK message back and sends the data to other nodes in the area in order to share it. In the case a terminal moves beyond a border of some areas, the terminal will dispose the holding data of the old area and begin to collect new data held in the new area from its neighbor nodes.

In order to avoid losing some data in an area, the terminals in the area calculate *delete count* as an indicator of data relocation to other nodes. When a terminal loses some data by overflow of its memory or disposition in moving from the area to another area, it will send a *delete count message* and the message will be flooded to the other nodes in the area. A delete count message includes the ID of the source node and a time stamp when data lost has occurred. The terminals will check the recent delete count messages and start relocation if the delete count exceeds the limit. In table 3, we outline our data relocation protocol.

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Table 4. Evaluation environment

- total disaster area : 1,200m × 1,200m
- area divided into : 400m × 400m
- # of victims : 1,000
- # of vehicles : 0, 100, 250, 500, 1000
- transmission range : handheld 100m, vehicular 200m
- packat size : 1KByte (1 packet has 10 users' data)
- bandwidth : 100KBytes/sec
- node mobility : random way point/urban area model

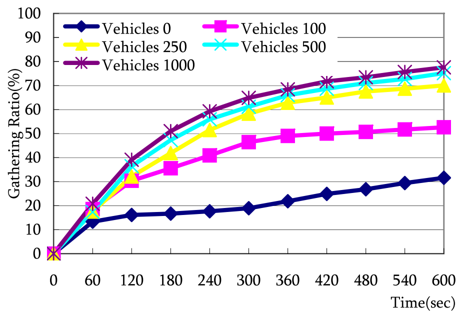

Figure 2. Affection of the number of vehicles

4 Evaluations

We have evaluated our system by simulation under the environment shown in Table 4. We have evaluated our system by *registration ratio* and *keeping ratio*. The registration ratio means the ratio of victims that receive ACK packet correctly. The keeping ratio means the ratio of the registered information that alive at the time.

At first, we have evaluated the affection of the number of vehicles in the disaster area. We have measured the registration ratio by changing the number of vehicles and Fig. 2 shows the increasing registration ratio with time elapsing. This result shows that the vehicles affect the registration ratio very much, since vehicles have much more memory and they also bring messages by moving from areas to areas.

Next, we have evaluated the affection of duration of the sleep mode by measuring the registration ratio with 1,000 vehicles for some sleep times (Fig. 3). From this result, we can see that the shorter sleep mode than two minutes does not affect the registration ratio and we can change the duration more aggressively.

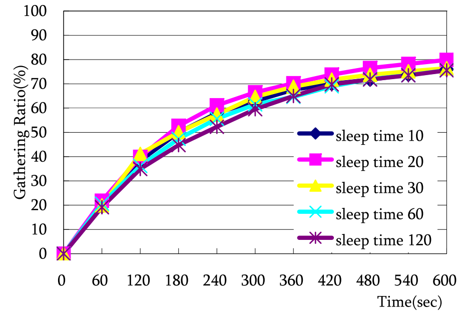

Figure 3. Affection of sleep time

At last, we have evaluated the affection of data relocation. Here, we have done two evaluations with 1,000 vehicles. One is evaluated based on the random waypoint mobility (Fig. 4(1)) where the victims can walk around multiple disaster areas rather freely. In another evaluation, we assume that most victims can move toward a shelter area located at the center of the disaster areas, and it is evaluated using a urban pedestrian flow (UPF) model proposed in [9](Fig. 4(2)) Here, we have produced an urban area model such that where the density of victims is higher at the center areas. For the both evaluations, the mobility of the vehicles is reproduced by NETSTREAM [12] such that each vehicle can drive along the roads with keeping the traffic rules. For the former model, the results are significantly different, since the victims can walk around multiple areas and the keeping data is lost very often. On the other hand, for the latter model, since the movements of victims are within fewer areas, the data keeping ratio is rather high for both the schemes. However, the without-relocation scheme, almost all the data is only kept in its home areas, but the with-relocation scheme, about a half of the data is kept in the neighbor areas redundantly. So the with-relocation scheme seems to be more scalable.

5 Conclusions & future works

We propose a data collection and management system for victims on disaster. In our system, the data will be collected by an ad-hoc network constructed by handheld and vehicular terminals. The collected data will be managed by such terminals. Since our system does not depend on any infrastructures, it is expected

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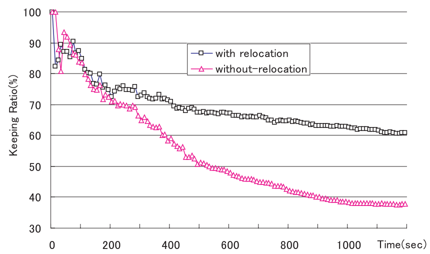
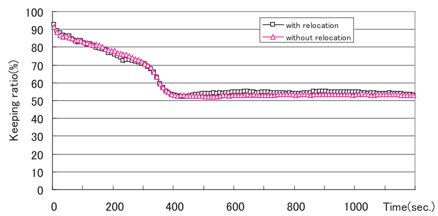


(1) Victims walk randomly



(2) Most of victims walk toward a shelter area

Figure 4. Affection of data relocation

to work under serious disasters. For future work, we are planning to implement a query access scheme and evaluate the scalability of our system. Also implementing our system for practical environment is an important subject.

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