A Demand-Oriented Information Retrieval Method on MANET

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Abstract

In urban areas including shopping malls and stations with many people, it is important to utilize various information which those people have obtained. In this paper, we propose a method for information registration and retrieval in MANET which achieves small communication cost and short response time. In our method, we divide the whole application field into multiple sub-areas and classify records into several categories so that mobile terminals in an area holds records with a category. Each area is associated with a category so that the number of queries for the category becomes the largest in the area. Thus, mobile users search records with a certain category by sending a query to nodes in the particular area using existing protocol such as LBM (Location-Based Multicast). Through simulations supposing actual urban area near Osaka station, we have confirmed that our method achieves practical communication cost and performance for information retrieval in MANET.

1. Introduction

Mobile terminals such as laptop computers, mobile phones, and PDAs are pervasive nowadays and their processing power is rapidly increasing. Many of these devices now have wireless communication capabilities such as IEEE 802.11 and Bluetooth. With these communication capabilities, mobile ad-hoc network (MANET, hereafter) can be formed for temporary network anywhere such as office, disaster area and battleground. In recent years, there have been many studies regarding to MANET. In urban areas including shopping malls and stations where many people are huddling, it is desired to utilize MANET to allow people to exchange various information which those people have obtained.

In this paper, we propose an information registration and retrieval method on MANET for exchanging information among people in urban areas. We assume that the information consists of a tag including location, keywords, and main data which can include text of any format, picture, video or audio.

It is desirable to satisfy the following four criteria when realizing the information retrieval system on MANET: (1) small power consumption; (2) correct operation even when there is only low communication bandwidth available; (3) small traffic amount; and (4) no concentration of load on particular terminals. This study aims to realize an efficient method which satisfies these criteria.

In the proposed method, the whole application field is divided into sub-regions called *area*s beforehand. The method classifies all user data called *record*s into categories, and observes demand for records per category at each area. Response time, communication bandwidth and battery consumption can be reduced by assigning records to terminals in the area where there is high demand for those records.

In order to evaluate effectiveness of the proposed method, we conducted simulations supposing actual urban area near Osaka station, Japan, with measured human density. The experimental results show that our proposed method achieves much better performance in terms of response time and amount of communication traffic than simple flooding method.

1.1. Related work

Xue et al. [5] have proposed a hierarchical addressing method for nodes on MANET. In the method, two dimensional area is divided into rectangular sub-areas, and one deputy node which manages addressing information is chosen for each sub-area. Although the concept of dividing geographical region into sub-areas is similar to our proposed method, this work is different from our work since our method does not have a deputy node for each area.

Ishihara et al. have proposed a location associated replica distribution method of data[3]. This method is similar to our proposed method in terms of finding an efficient data replication on ad-hoc network. This method is different from our method since it does not place data according to demand.

MobiREAL [1] is a MANET simulator with a realistic mobility model of humans. Although we have not used MobiREAL to evaluate our method, we used the observed human density and pedestrian scenario proposed in [2].

ClassID	Counts (1st)	Area (1st)	Counts (2nd)	Area (2nd)
000	8	A1	-	-
001	10	A1	-	-
002	3	A1	-	-

Table 1. Query count table of area A1

ClassID	Counts (1st)	Area (1st)	Counts (2nd)	Area (2nd)
000	8	A1	5	A2
001	11	A2	10	A1
002	3	A1	1	A2

Table 2. Updated query count table of area A2

2 Proposed Method

In this section, we define the terms used in this paper, and describe the target information retrieval system. Then, we propose basic ideas to realize the system in MANET.

2.1 Definition

We suppose a mobile terminal (called *node*, hereafter) such as note PC, PDA or mobile phone. Each terminal is carried by a person and therefore each node moves. The mobile ad-hoc network consists of these nodes. Each node joins and leaves the ad-hoc network anytime. We assume that each node has a unique ID number and can know its geographical position by GPS. The geographical region where the proposed method is operated is assumed to be predefined.

We assume that some mobile nodes have information. We call the minimum unit of information as *record*. A record is a combination of ID number, time stamp representing the time when the record was created, position of the node where the record was registered, category ID, record body such as picture images or text of any format (hereafter, called *main data*), and some auxiliary fields such as position and prices.

ID number is a unique integer number attached to a record, which is generated from the ID number of its owner node and time stamp. The system has a set of keywords, each of which corresponds to one of the predefined categories. Each user attaches keywords to the information record when he/she resisters it. Conditions regarding to the main data cannot be specified as a search condition of the record.

2.2 Target Information Retrieval System

In the system, users register or retrieve records by queries which specify conditions. As response of a query, a user obtains all records which match to the condition specified in the query. The condition can be any logical expression including category ID, position, prices and so on.

2.3 Basic Ideas

If all of registered records are replicated in all nodes in MANET, the average response time becomes minimum. However, the replication cost also becomes high. In the proposed method, we replicate records with a category ID only in the nodes in the area with the largest demand for the category (called *most demanding area*). For this purpose the system divides all records into multiple sets. Each set is called a *class*. We assume that the number of matched records of each class largely depends on the geographical places where the corresponding queries are sent. In our method, we let the system autonomously find the best places where records should be replicated per class so that the average response time for each query is minimized.

2.3.1 How to find the most demanding area

To find the most demanding area for each class, we let all nodes count the number of matched queries for each class, and sum them up at regular intervals at each area. The results are maintained in a table called the *query count table*.

We determine the most demanding area and the second most demanding area as follows. Nodes in each area (e.g. A1) floods information of the query-count table (Fig. 1) and area ID at regular intervals.

When a node in area A2 neighboring A1 receives the table sent from a node in A1, it compares entries of the table and its own table, and updates the table so that each table entry has higher value between two tables (Table 2). Then the table is flooded again. After all areas update the table, all nodes know which areas are the most and the second most demanding areas. We assume that each node has a function which translates a search condition of a given query to candidate classes which can match to the query. The sender node of each query directly sends messages to the most demanding areas of these classes. We use Location-Based Multicast [4] (LBM, hereafter) as communication protocol for sending these messages.

2.3.2 How to replicate records

The most demanding area for each class may change as time passes. In our method, in order to cope with this problem, we let nodes in the second most demanding area also replicate records, under the assumption that demand changes only little by little. The amount of records replicated in the nodes in the second most demanding area is decided in proportion to the ratio of the numbers of queries between the most and the second most demanding areas.

3 Implementation

We have implemented the proposed method in our simulator.

In our simulator, the transmission range of all nodes are assumed to be identical. We assumed that the nodes within the transmission range to receive the packet at 100% of probability as long as packet collision does not occur, and the nodes outside the range will not receive a packet at all. The simulation proceeds at regular intervals (i.e., time slot). Each node can transmit and receive one packet per time slot. We assumed that each time slot corresponds to 10msec. Time To Live of the message is set to be 5 seconds, which is calculated by Wireless LAN's achievable transmission speed (i.e., 2Mbps), and each packet has a length of 1,500byte whose transmission duration is 6msec. We added overhead of processing packets by software.

Our simulator emulates carrier sense of CSMA/CA by letting each node sense if the other node within the transmission range is sending a packet. If the node finds other nodes sending, it will not send a packet in the time slot. If two different nodes within a transmission range transmit packets in a time slot, we consider that collision occurred between these packets. Each transmitted packet is inserted into a transmission queue of a sender node before transmitted to its radio range, and one packet from the queue is transmitted per time slot. If the node senses the other node within the transmission range transmitting a packet, transmission of the packet at the end of the queue is postponed by one time slot.

Communication protocols used in our implementation are the following: (1) Flooding protocol: used when a message is sent to the entire ad-hoc network; and (2) Location-Based Multicast (LBM) protocol [4]: used when sending a query or a record to nodes in a particular area.

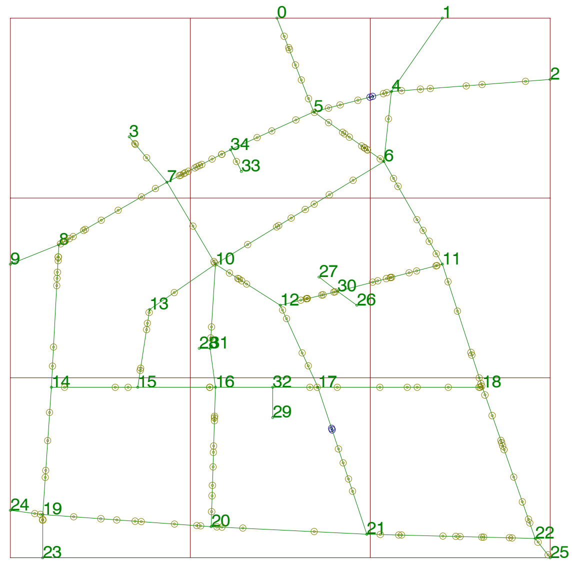

Figure 1. Pedestrians on the road

In our implementation, we devised the following techniques to send packets.

Decimation of packets : In order to reduce congestion of network, packets are decimated according to the distance between nodes. The probability of decimation is increased as the distance between nodes is smaller.

Prioritization of packets : Same packets may reach its destination through various routes. In order to transfer a packet to its destination as fast as possible, we prioritized packets as follows: (1) Newly received packet has higher priority; and (2) the packet forwarded by distant nodes has higher priority.

Duplication avoidance: Flooding and LBM are designed so that intermediate nodes relay packets with the same ID only once. Besides it, we designed destination nodes to respond to a query only once, and intermediate nodes relay response messages with same query ID only once.

4 Experiment

In order to evaluate how properly our proposed method works, we have conducted experiments to investigate the number of all transmitted messages and response time. The target geographical region is the 500m $\times$500m region around Osaka Station. The region contains roads with 35 vertices and 44 edges, as shown in Fig.1. We placed nodes on the roads according to the actual observed density. A screen shot of the simulator is shown in Fig.1.

We used the following configuration: The size of each area is 167m $\times$ 167m. The number of nodes is 1,000. Nodes are assumed not to move, for simplicity. The number of the area is $3 \times 3 = 9$. The transmission radius is 100m. We replicated records to all nodes in the most demanding area.

We let randomly selected node send a query packet every five seconds. One node is designated to match two records to a query and reply two data packets. Experiments are performed five times, each of which is 30 cycles of sending query and recieving reply data. The experimental results averaged over five simulation runs are shown in Table 3.

4.1 Evaluated items

We call the number of replies except duplicated replies if there were no packet loss **the number of expected replies**.

We examined the following metrics through the experiments.

The number of received replies : The number of actually received replies excluding duplicated replies. This should be less or equal to the number of expected replies.

Reply loss ratio = (The number of expected replies − the number of received replies) / the number of expected replies

Redundancy = (The number of all reply messages received by the node which originated the query) / (the number of received replies) [1]

Average response time : Average time taken from the time of sending a query, to the first reception of a reply message.

Average hop count : Average hop counts in round trip routes between query sender nodes and the nodes sending query replies which were recieved by the sender nodes first.

The number of all messages : The number of packets sent in the entire network.

4.2 Experimental Result

We compared the result between the following cases: (i) Records are retained by nodes in the most demanding area (the proposed method); (ii) Records are retained in the least demanding area; and (iii) Records are retained in the terminals which created them, and retrievals are performed using flooding protocol [2]. The number of nodes in the simulation is 1000. The experimental result averaged over five simulations are shown in Table 3.

Table 3 shows that the case (i) using the most demanding area (proposed method) achieves the lowest reply loss ratio, and the case (iii) with flooding has the highest loss ratio. For redundancy, the case (iii) with flooding is the worst, which is significantly worse than the other two methods which use LBM. Regarding to average response time and average hop count, our proposed method (case (i)) achieved the best performance.

[1] In the proposed method, a node that originates a query receives multiple same replies.

[2] Packet decimation is not done when flooding is used (see section 3)

	case(i) Most Demand Area	*case(ii) Least Demand Area*	*case(iii) Flooding*
Received Replies	59.6	57.6	51.6
Reply Loss	0.67%	4.0%	14.0%
Redundancy	69.1	76.3	224.1
Response Time(sec)	0.33	0.39	1.32
Average Hops	5.8	7.9	6.6
All Messages	38,637	42,195	224,512

Table 3. Experimental Result

The simulation results when the number of nodes are set 100, 200, 500 and 1000 are shown on Figs. 4 to 2, respectively. Regarding to Fig.4, the number of messages when the number of nodes is 200 is significantly higher than when it is 100, but the number of messages does not increase further when the number of nodes is more than 200. This indicates that there is message congestion. Fig. 5 shows that the case (iii) with flooding has the lowest reply loss ratio, and the ratios for other methods are not as low as the case (iii) with flooding when the number of nodes is less than 200. This is because there can be no route to the destination if LBM is used in these cases. Fig. 2 shows that the proposed method (case(i)) with the most demanding area has the shortest average response time in any cases.

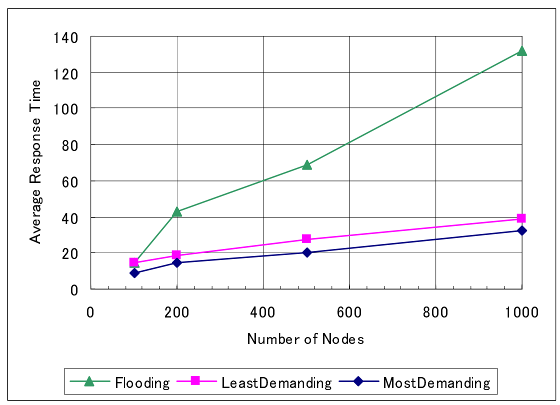

Figure 2. Response Time

5 Conclusion

We have proposed an information retrieval method on MANET that achieves low communication traffic and short response time. In order to evaluate the proposed method, we conducted simulation using actual geographical information with measured pedestrian density in Osaka city. We confirmed that our method achieves response time shorter than the method using flooding.

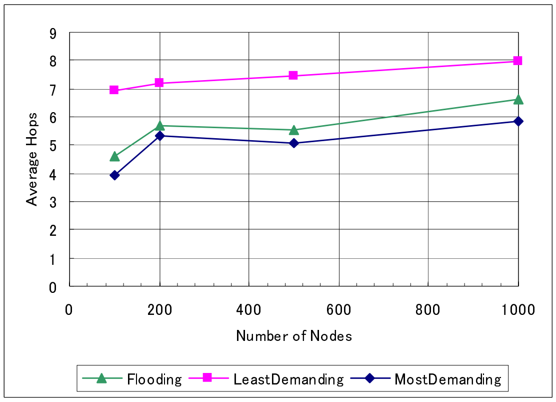

Figure 3. Average Hop Counts

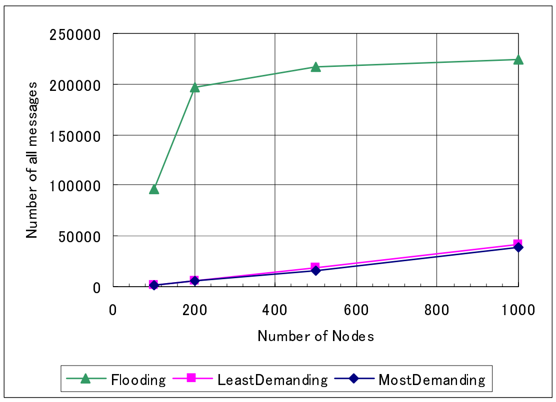

Figure 4. Number of messages

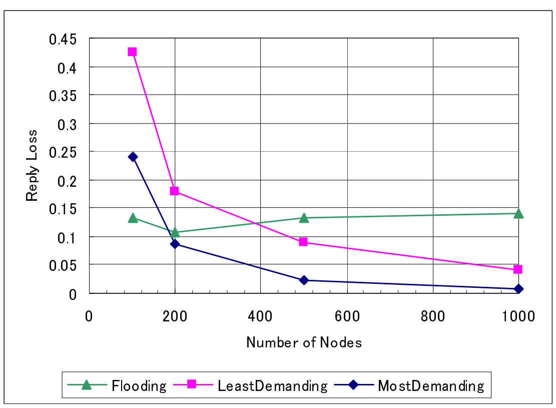

Figure 5. Reply Loss

Estimating the overhead of control messages for finding the most demanding areas and record replication cost is part of future work.

Also, we are planning to conduct simulations under the conditions where pedestrians move along the roads with realistic pedestrian density on each road.

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