A Negative Location-based Information Dissemination Method in Mobile Ad Hoc Networks

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***Abstract*—Location-based services (LBSs) are important applications for mobile users. We consider an application in which the source node periodically disseminates location-based information in mobile ad hoc networks (MANETs). We define beneficial information as that which may be of benefit to mobile users planning to pass near the location related to the information. However, typically, mobile users change their route or travel direction when the mobile node receives beneficial information such as traffic jam and accident information (we call these information the *negative location-based information*). Thus, a significant problem lies in determining the proper target area for the dissemination of such information in dynamic networks because the source node is difficult to effectively know where to disseminate it. In this paper, we propose a novel location-based information dissemination method in MANETs by use of some fixed nodes. Our proposed method requires neither a positioning system, nor previous knowledge, to efficiently disseminate the information. However, the fixed nodes autonomously expand the relevant dissemination area. Through simulation experiments, we confirm that the proposed method suppresses ineffectual overhead, and that mobile users can efficiently and early receive the beneficial information.**

***Keywords*-mobile ad hoc networks, data dissemination, location-based system**

I. Introduction

Location-based services (LBSs) which offer location-based information have been attracting increasing research interest. Users with portable devices equipped with location sensing and cellular network connection facilities are able to retrieve position specific information (e.g., nearby restaurant location and price information). However, receiving location-based information through a cellular network is an expensive and inefficient approach, when the information of interest is generated at a location only a small distance from the user's position.

Mobile ad hoc networks (MANETs), including direct communication between vehicles, are relatively new approaches to sharing up-to-date information related to a given geographical environment. In MANETs, every mobile node plays the role of a router, and the nodes communicate with one another.[1] For example, in an application of intelligent transportation system (ITS), sharing real-time information on traffic jams or accidents among nearby drivers and passengers is expected to enhance carbon reduction, safety and comfortable driving. However, though such technology has attracted great interest both from industry and the research community, practical services capable of disseminating location-based information using MANETs are still not available. This is partly because applications utilizing such networks to disseminate location-based information face some major issues: limited bandwidth and dynamic mobility patterns. Various strategies for data dissemination in MANETs and vehicular ad hoc networks (VANETs) have been proposed [6]. Most of such strategies pre-designate the *dissemination area*, which is the area that should be sent the information, but in realistic environments the dissemination area is unknown without previous knowledge such as a digital map and statistics. Hence, the information basically needs to be disseminated to a wide area, but this causes unnecessary overhead. Moreover, those methods assume using a positioning system such as the global positioning system (GPS) to disseminate the information, but it is not true that every node knows its position.

In [1], we proposed a novel location-based information dissemination method in MANETs by use of some fixed nodes, which requires neither a positioning system nor a previous knowledge. We assume that beneficial information is defined as that which may be of benefit to mobile nodes planning to pass near the location related to the information. In this method, mobile nodes which receive the beneficial information come near the source node and reply back a message to the source node. After receiving the message from the mobile nodes, the source node knows the area which mobile nodes that will pass near the source node exist, i.e., the source node knows the proper dissemination area (we describe this method in detail in Section II). However,

[1]We call the mobile user with portable device or the vehicle the *mobile node* or *node*

this method does not account for changes in the route or travel direction of mobile nodes (e.g., vehicles) receiving the information, and such changes are very common, for example when traffic jam or accident information is received (we call the location-based information that mobile nodes change their route or travel direction the *negative location-based information*). In this case, since the source node cannot know the proper dissemination area in advance.

Therefore, in this paper, we propose a method for disseminating negative location-based information in MANETs by use of some fixed nodes, which is capable of adapting to cases where the mobile node, having received the beneficial location-based information, changes its route or travel direction.[2] In addition, the proposed method requires neither a positioning system nor a previous knowledge for dissemination of the information, but instead expands the dissemination area on the fly. In this novel method, mobile nodes receiving the beneficial location-based information send the message to a nearby fixed node, and the fixed nodes receiving the messages autonomously expand the dissemination area. If the mobility pattern changes without regard to the disseminated location-based information, the effective dissemination area may also change. Thus, to avoid the ineffective dissemination of information, the dissemination area is updated on the fly.

Our main contributions of this paper are as follows.

- The proposed method does not predetermine the dissemination area of the information, but instead the dissemination area is effectively expanded so that mobile nodes receive the beneficial location-based information as early and efficiently as possible.
- Since the proposed method requires neither a positioning system nor previous knowledge, it offers a more realistic and flexible solution than those currently available.
- Through simulation experiments, we verify that our proposed method suppresses unnecessary overhead, and that mobile nodes planning to pass near the source node can receive the information early and efficiently.

The remainder of this paper is organized as follows. In Section II, we discuss related work. In Section III, we describe the assumed environment. In Section IV, we present the location-based information dissemination method. In Section V, we describe the results of the simulation experiments. Finally, in Section VI, we conclude this paper.

II. Related Work

Our proposed method is related to a flooding mechanism which disseminates information to a local area where mobile nodes exist. First of all, to the best of our knowledge, there are no work which aims to efficiently disseminate the information to a target area without previous knowledge and location information except for our previous work [1].

Flooding-based approaches [3], [5] are applicable without any such knowledge and without positioning systems. In the simple flooding algorithm, each node rebroadcasts a message to its neighbors upon receiving the message for the first time. Its advantages are the simplicity and reachability, but it has a problem for scalability due to the limited bandwidth of wireless networks. In [4], the source node efficiently broadcasts information to all nodes in the entire VANET without infrastructure support by sending a message only if neighbors do not send one. Few studies, however, have addressed the question of how to determine the relevant dissemination areas and how to adapt these areas to mobility patterns. Moreover, most of the proposed VANET systems require the knowledge of the road layout and GPS positions. Those methods cannot adapt to disseminating the information through nodes that do not know their position and previous knowledge. The method proposed in this paper differs from such conventional methods in several respects: the dissemination area is adapted to mobility patterns, and no positioning system or previous knowledge is required.

Our previous method [1] is most closely related to the method proposed in this paper. In [1], we proposed a location-based information dissemination method that requires neither a positioning system nor previous knowledge. [1] focuses on information which may be of benefit to mobile nodes planning to pass near the location related to the information and receivers travel to the location (or do not change the route) such as restaurant information or accidental alert. To the disseminated information is added the identifier of any fixed node that relays the information (the accumulated identifiers are called the *route record*). Since the mobile node receiving the information sends an acknowledgment (ACK) including the route record to the source node, the source node can know where to disseminate the information (this scheme is called *ack-carry*). At next sending, the location-based information includes the identifiers of fixed nodes in the route records of the ACKs, and the fixed nodes included in the information reset the TTL (i.e., expand the dissemination area). Therefore, in this method, the source node can know where to disseminate the information, without a positioning system or previous knowledge using the ack-carry scheme. However, this method does not account for changes in the route or travel direction of mobile nodes receiving the information (negative location-based information). Since the ack-carry scheme does not work, in such cases, and the source node cannot know where to disseminate the information, a new approach is necessary to expand the dissemination area.

III. System Model and Problem Formulation

In this section, we describe the assumption of the system model.

[2]We call the negative location-based information the location-based information or the information simply.

A. Assumptions

The location-based information is defined as information that is associated with a certain location and should be delivered as early as possible to mobile nodes which will pass near the location. The negative location-based information is disseminated by periodical flooding from a source node. For simplicity, we assume that all nodes know their movement path (route) in near future and can judge whether the information is beneficial or not, but do not know their location.

We assume that mobile nodes have some restricted mobility pattern. Specifically, the movement of mobile nodes is constrained to roads, which have a static structure. Mobile nodes can only move in either direction on a given road. In a real environment, the movement of mobile nodes is biased by several static and dynamic factors such as road topology, traffic rules, surrounding facilities, time of day and day of the week. Therefore, the mobility pattern in the entire area is typically skewed (e.g., many nodes are located in a particular direction on a particular road). To utilize bandwidth efficiency, the dissemination areas of location-based information should be adapted to such mobility patterns and their dynamic change. For ease of explanation, we assume each mobile node has sufficient storage to receive all information messages (however, nodes may not receive all information due to packet losses and communication failures).

In addition to mobile nodes, we assume a small number of fixed nodes which are installed on traffic lights and/or lampposts. The fixed nodes are used for identifying and expanding dissemination areas, but need not form a mesh network only by themselves. In our simulations, described in Section V, the fixed nodes are located on roads at intervals 1.5 times larger than their wireless communication ranges. Therefore intermediate mobile nodes are necessary for sending messages to distant nodes through multi-hop relay.

IV. Proposed Method

In this section, we explain the location-based information dissemination method proposed in this paper. We explain the initial state of dissemination in our proposed method and how fixed nodes expand the dissemination area. Then, we explain the strategy to adapt to dynamic mobility pattern change.

A. Initial dissemination

In our assumed environment, a source node does not initially know where to disseminate the information. Therefore, when the source node wishes to disseminate some information, it disseminates a *information message* to a small area by k-hop flooding in order to avoid inefficient dissemination. k-hop flooding is a flooding scheme which limits broadcast message travel to a maximum of k hops, and is generally implemented using small TTL values. The disseminated information message here includes the identifier of the last fixed node to relay the message (the initial identifier is that of the source node). When a node relays the message, it stores the message, and rebroadcasts the message, after updating the TTL. If the receiver is a fixed node, it stores the identifier included in the message and updates the identifier included in the message to its own identifier. The fixed nodes store such identifiers for use in expanding the dissemination area. The procedures are shown in Algorithm 1. In Algorithm 1, IM denotes an information message and ϑ (initially, $\vartheta \leftarrow \phi$) denotes a set of identifiers included in the information message which fixed nodes are stored.

Algorithm 1 Initial dissemination

Source node sets k and its identifier to an IM
Source node broadcasts the IM
if Node receives the IM at first **then**
  stores the IM
  decreases the TTL by 1
  if The node is a fixed node **then**
    $\vartheta \leftarrow \vartheta \cup$ the identifier in IM
    updates the identifier in the IM to its identifier
  end if
  if TTL > 0 **then**
    broadcasts a copy of the IM
  end if
end if

Figure 1 shows an example of the dissemination of information by 3-hop flooding. When a fixed node H_i originates location-based information (i.e., H_i is the source node), it broadcasts information messages with a TTL of 3 and the identifier of H_i. When a mobile or fixed node receives an information message which has not been previously received, the node decrements its TTL by one. If the TTL is larger than 0, the node rebroadcasts a copy of the message. Thus, the mobile node M_i, which received the information message from H_i, rebroadcasts it with a TTL of 2. Similarly, the fixed node H_j, which is not within the wireless transmission range of H_i, will receive the information message with a TTL of 2 from some mobile nodes (such as M_i), and will rebroadcast it after updating the TTL as 1, including in the information message the identifier of the fixed node H_j. From the identifier of the fixed node included in the information message, H_j knows that H_i is a fixed node closer to the source node than itself (here, H_j knows that H_i is the source node). Whereas, a mobile node, M_j, which receives the information message from H_j with a TTL of 1, will not rebroadcast it because its TTL value has reached 0. Thus, only mobile nodes around H_i and H_j can receive the information originated by the source node H_i.

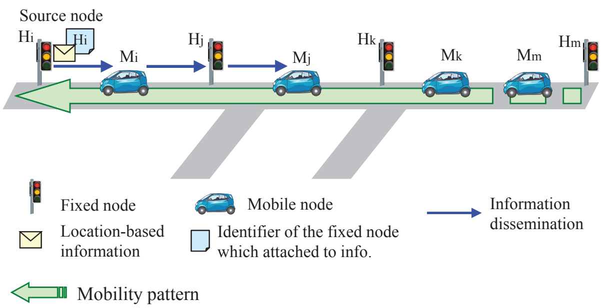


Figure 1. Snapshot of information dissemination, where H_i being disseminating the information message and M_i, H_j, and M_j receive it.

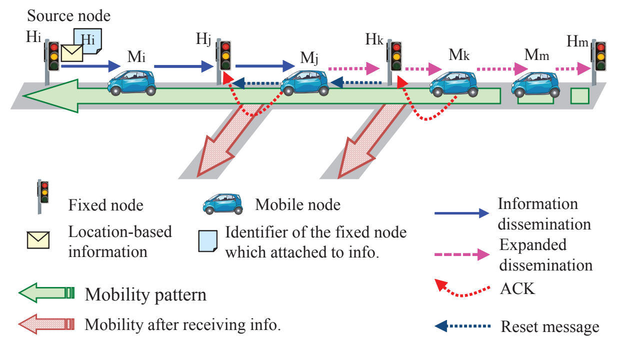


Figure 2. Snapshot of an information dissemination, where H_j and H_k receive an ACK from mobile nodes, and expand the dissemination area.

Algorithm 2 Expanding dissemination

if Mobile node receives an IM which includes beneficial information **then**
  sends back an ACK to the fixed node included in the IM
end if
if Fixed node receives an ACK **then**
  resets the TTL to k from next dissemination
  sends a RM to ϑ.
end if
if Fixed node receives a RM **then**
  $\psi \leftarrow \psi \cup$ the identifier in the RM
  resets the TTL to k from next dissemination
end if

B. Expanding dissemination

If the mobile node that receives the information plans to pass near the source node (i.e., the information is beneficial for the mobile node), the mobile node sends back an ACK to the fixed node included in the information message. The fixed node receiving the ACK is thus made aware of the existence of mobile nodes planning to pass near the source node nearby, and this means that when it receives the information message, it resets the TTL to k (i.e., expands the dissemination area). The fixed node receiving the ACK sends a *reset message* to the fixed node whose identifier has stored to notify the fixed node of having reset the TTL. The fixed node that receives the reset message stores the sender's identifier, and resets the TTL, since it knows that a fixed node more distant from the source node than itself has reset the TTL. To reduce overhead, the mobile node that has sent the ACK does not send back the ACK when it receives the information message from the same source node in different locations. Similarly, the fixed node that has sent the reset message does not send the reset message again. The procedures are shown in Algorithm 2. In Algorithm 2, RM denotes a reset message and ψ (initially, $\psi \leftarrow \phi$) denotes a set of identifiers included in the reset message.

Figure 2 shows an example of expanding the dissemination area after the procedure in Figure 1. A mobile node M_j, which plans to pass near the source node, sends an ACK to the fixed node H_j, which relayed the information message last. Hence, when H_j rebroadcasts the information message, it resets the TTL to 3 (here, it does not send a reset message because it has stored the identifier of the source node). H_k also receives the ACK, and it sends a reset message to H_j, so that H_j knows that H_k has reset the TTL. H_j may not itself receive the ACK because of mobile node route changes, but it does not stop resetting the TTL, because it knows that there are mobile nodes near the farther fixed node H_k which plan to pass near the source node.

C. Strategy for dynamic mobility pattern change

When the mobility pattern changes without regard to the disseminated information, the information, which continues to be sent out, is inefficiently disseminated. To avoid the resulting increase in unnecessary overhead, our proposed method uses a *delete message*. If a fixed node that has reset the TTL does not receive an ACK for a certain length of time or a reset message, it stops resetting the TTL and sends the delete message to the fixed node to which it has sent the reset message. The fixed node receiving the delete message deletes the identifier of the fixed node that sent the delete message. When a fixed node receives delete messages from all the fixed nodes that have sent the reset message, and does not receive an ACK for a certain length of time, it also stops resetting the TTL and sends a delete message to the fixed node to which it has sent the reset message. As a result, our proposed method can efficiently shrink the dissemination area.

V. Simulation Experiments

In this section, we describe the results of simulation experiments to evaluate the performance of our proposed method. In the simulations, we used the QualNet4.0 network simulator [8].

A. Simulation Model

The simulation area consists of 1,500 × 2,500 meters^2 of flat land. Figure 3 shows the road topology used in the simulations. The numbers with arrows in Figure 3 denote traffic

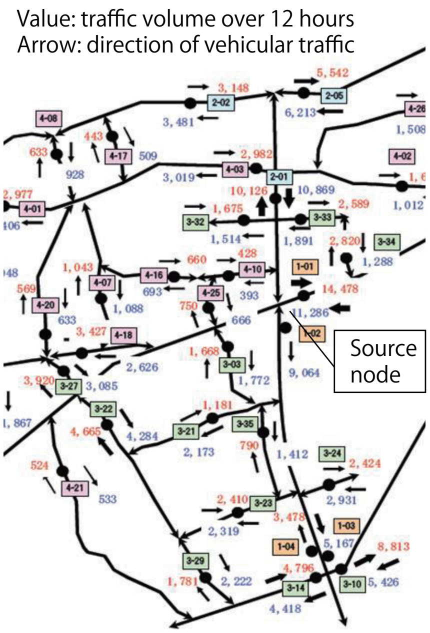


Figure 3. Road and traffic information

volume on the arrow direction. The road topology and traffic volume are based on 2009 information for Minoh City, Japan [7]. The source node is placed at an intersection where traffic volume is relatively large, located almost in the center of Figure 3. The fixed nodes are placed at 200 meters intervals along the roads. The source node periodically disseminates the information whose size is 128 bytes by k-hop flooding, at intervals of I seconds. The node receiving an information message rebroadcasts it after waiting a random period in the range of 0 to 2 seconds, to avoid packet collisions caused by nearby nodes broadcasting messages at the same time.

Mobile nodes set out from the ends of the respective roads, at intervals corresponding to the traffic volume. Each mobile node decides its route by using Dijkstra's shortest path algorithm, where the link cost is the road distance weighted by the traffic volume. The mobile nodes move at a speed of 15 meters/second. We assume that each node transmits messages using a standard IEEE 802.11b device whose data transmission rate is 11 Mbps. The transmission power of each node is determined so that the radio communication range becomes about 130 meters.

The total simulation time is 27,000 seconds. We evaluated the following metrics after completing the simulation. Here, mobile nodes that exist on the roads at the end of the simulation are not considered in calculations of those metrics.

- *Number of effective messages*: the total number of times that each mobile node receives information messages of interest which were generated by the source node. This metric is calculated as the total number for all mobile nodes. Here, information messages of interest are defined as that those which prompt the mobile nodes which received the messages could send the ACKs to the fixed node (i.e., the mobile nodes planned to pass through the source node).
- *Maximum delivery distance*: the maximum distance covered by effective messages received by mobile nodes. Here, note that greater maximum delivery distance means better performance because mobile nodes can receive the information of interest earlier.
- *Overhead*: the total volume (in bytes) of delivered messages during the simulation period.

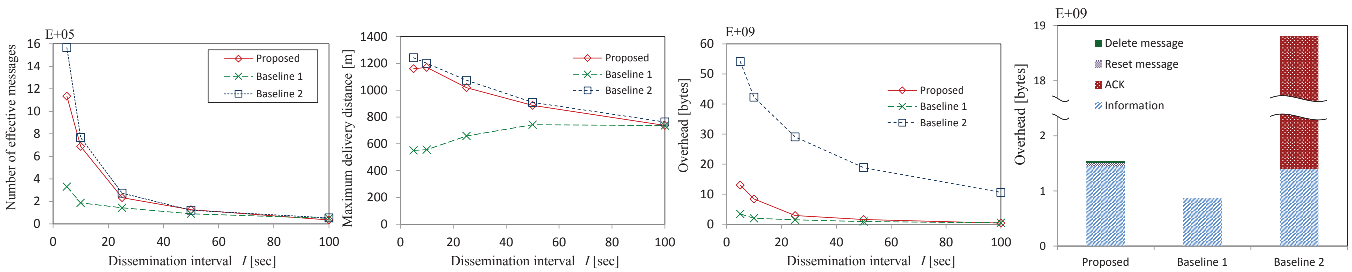
We compare the performance of our proposed method with the following methods as baselines.

- Baseline 1:
  A mobile node that receives the beneficial information sends an ACK to the fixed node that relayed the information last the same as the proposed method. The fixed node that receives the ACK resets the TTL. If the fixed node that resets the TTL does not receive an ACK for a certain length of time, it stops resetting the TTL. This certain length of time is set as $(2 \times I)$ in this simulation. The difference between this baseline method and the proposed method in this paper is that this baseline method does not send reset and delete messages, and thus the fixed nodes cannot know whether other fixed nodes have reset the TTL or not.
- Baseline 2:
  A mobile node that receives the beneficial information message sends an ACK to the source node by multi hop relay so that the source node can know where to disseminate the information message. The source node attaches the fixed node identifiers in the received ACK to the information message, at the next timing. If a fixed node receives the information message and its own identifier is included, it resets the TTL. If the source node does not receive the identifier of a given fixed node for a certain length of time (again $(2 \times I)$), it does not include that identifier in the information message at its next sending. In this method, the source node can know where to disseminate the information, but significant overhead is likely to be involved.

B. *Effects of dissemination interval I*

We examine the effects of the dissemination interval I. The initial TTL in our proposed method and two baselines is set to 3 hops (3-hop flooding) because 3 is the smallest TTL to deliver an information message to mobile nodes around fixed nodes next to the source node. In our proposed method, the time delay before sending a delete message T is 450 seconds.

Figure 4 shows the simulation results. In these graphs, the horizontal axis indicates I. The vertical axes indicate, respectively, the number of effective messages in Figure



(a) Number of effective messages (b) Maximum delivery distance (c) Overhead (d) Analysis of overhead when $I = 50$

Figure 4. Effects of dissemination interval, I

4(a), the maximum delivery distance in Figure 4(b), and the overhead in Figure 4(c). Figure 4(d) shows the analysis of overhead when $I = 50$.

From Figures 4(a) and (b), we can see that our proposed method and Baseline 2 expand the dissemination area, while Baseline 1 does not expand the dissemination area much. Our proposed method and Baseline 2 are better choice to disseminate the information widely and quickly then Baseline 1. The dissemination area in our proposed method and Baseline 2 diminishes as I increases because only mobile nodes near the source node (who will probably pass near the source node) receive the information. On the other hand, the dissemination area in Baseline 1 is small when I is small. This is because since they do not receive ACKs owing to mobile nodes having changed their route or travel direction after receiving the information, the fixed nodes near the source node stop resetting the TTL after a short time.

From Figure 4(c), our proposed method achieves significantly smaller traffic than Baseline 2 because Baseline 2 sends an ACK message to the source node through long paths (see Figure 4(d)).

Figure 4(d) shows the analysis of overhead when $I = 50$, where the number of effective messages and maximum delivery distance in our proposed method and Baseline 2 become similar. This figure shows that the overhead for sending the information in our proposed method and in Baseline 2 is almost the same. These results suggest superior performance, viz. overhead, in comparison to Baseline 2. In addition, Figure 4 (e) shows that the overhead for sending reset and delete messages in our proposed method is relatively small.

VI. Conclusion

In this paper, we proposed an effective negative location-based information dissemination method. In our proposed method, mobile nodes receiving the information send back ACKs to the respective fixed nodes, and such ACKs inform the fixed nodes of mobile nodes to which the information is beneficial. The dissemination area can be efficiently expanded. We conducted some simulation experiments and confirmed that our proposed method involves low overhead, and achieves broad and effective dissemination.

Acknowledgments

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References

[1] T. Fujii, M. Kaji, Y. Sasaki, T. Hara, and S. Nishio, "A flooding control method with ack-carry for location-based information dissemination in mobile ad hoc networks," in SAINT, pp.128-135, 2011.

[2] B. Gedic and L. Liu, "MobiEyes: a distributed location monitoring service using moving location queries," IEEE Trans. on Mobile Computing, vol. 5, no. 10, 2006.

[3] H. Liu, X. Jia, P.J. Wan, X. Liu, and F.F. Yao, "A distributed and efficient flooding scheme using 1-hop information in mobile ad hoc networks," IEEE Trans. on Parallel and Distributed Systems, vol.18, no.5, pp.658–671, 2007.

[4] F. J. Ros, P. M. Ruiz, and I. Stojmenovic, "Acknowledgment-based broadcast protocol for reliable and efficient data dissemination in vehicular ad hoc networks," IEEE Trans. on Mobile Computing, vol. 11, no. 1, 2012.

[5] Y. Sasson, D. Cavin, and A. Schiper, "Probabilistic broadcast for flooding in wireless mobile ad hoc networks," in WCNC, pp.1124–1130, 2003.

[6] Z.C. Taysi and A.G. Yavuz, "Routing protocols for GeoNet: a survey," IEEE Trans. on Intelligent Transportation Systems, vol.13, no.2, pp.939–954, 2012.

[7] The official website of the municipality Minoh city, Japan, URL http://www.city.minoh.lg.jp/index.html/.

[8] Scarable Network Technologies: Creators of Qualnet Network Simulator Software,
URL http://www.scalable-networks.com/.