DTN에서 페리와 이동노드 기반 계층적 메시지 전달 기법

(A Delivery Scheme for Hybrid Ferry-Mobile Node Messages in DTNs)

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요 약 기존 메시지 페리 방법에서는 페리만이 분리된 네트워크 사이에서 메시지를 전달한다. 이 논문에서는 지연 허용 네트워크에서 메시지 전달 지연을 줄이기 위해 페리와 이동 노드 모두가 메시지를 전달하는 새로운 방법을 제안한다. 우리는 메시지 전달 지연, 처리율, 페리 버퍼와 이동 노드 버퍼 사용량을 통하여 기존의 메시지 페리 방법과 성능을 비교평가 한다.

키워드 : DTN, 메시지 페리, 혼합된 메시지 전달, 루럴 빌리지

Abstract In traditional message ferrying schemes, only ferries carry messages between partitioned networks. In this paper, we propose a new approach to make both ferries and mobile nodes carry messages so that we reduce message delivery delay in disruption tolerant networks. We evaluate our scheme against conventional message ferrying in terms of message delivery delay, throughput, ferry buffer usage and mobile nodes buffer usage.

Key words : DTN, Message ferry, Hybrid message carrying, Rural village

1. Introduction

A mobile ad hoc network (MANET) has no fixed infrastructure and is a self-configuring network of mobile routes connected by wireless links. The routers are free to move randomly and organize themselves arbitrarily. The network's wireless topology therefore may change rapidly and unpredictably. In MANET, nodes can directly communicate with each other if they are within each other's radio range. Node mobility, however, causes frequent changes in the network topology; network partitions occur frequently and can last for a long period of time. In addition, physical obstacles and limited radio range may prevent nodes from communicating with each other.

Recently, in order to support intermittent connection, the Disruption Tolerant Networks (DTNs) concept was introduced [1,2]. DTNs support communication between intermittently connected nodes even if the end-to-end path does not exist at the moment. They also tolerate delay on the path and deliver data using store-and-forward message switching.

Message Ferry (MF) is one approach that delivers data in DTNs based on the store-and-carry-forward scheme. The MF scheme is a proactive approach for routing in disconnected ad hoc networks. It addresses the disconnection problem by introducing non-randomness to provide connectivity. In this scheme, the network devices are classified as message ferries or regular nodes based on their roles. Ferries are devices with the responsibility of carrying messages between disconnected nodes, whereas

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regular nodes are devices assigned tasks in the deployment area. Ferries move around the deployed area according to known routes, collect messages from the sending nodes and deliver messages to their destinations or other ferries [3].

Up to now, most of the research on MF focused on ferry route design where ferries traverse efficiently [4-6], and on ferry replacement protocol which replaces the failed ferry using mobile nodes or different ferries [6,7]. In the most of related MF scheme, data are only carried by ferries. For example, if rural villages have MANETs and are very far away, they can communicate with each other only by ferries. This communication can cause long message delivery delays in DTNs.

The key contribution of this paper is an approach that makes both periodic ferries and mobile nodes carry messages, whereas traditional MF schemes make only ferries carry messages. In rural village networks, mobile nodes would visit the city from the villages. For example, people would visit hospitals, the post office and shopping malls in the city. Hence, we make use of the visiting node to carry data to different villages. This approach achieves less message delivery delay, a higher number of delivered messages and less resource use, especially for buffer to store messages.

The remainder of this paper is organized as follows: Section 2 presents a brief description of related work. In Section 3, we describe our proposed protocol with network model and protocol behavior. In Section 4, our proposed scheme is evaluated. Finally, a brief conclusion follows in Section 5.

2. Related Works

In [8], the authors propose the epidemic routing protocol for intermittently connected networks. When a message arrives at an intermediate node, the node floods the message to all its neighbors. Hence, messages are quickly distributed through connected portions of the network. The epidemic routing then replies when coming into contact with another connected portion of the network through node mobility. This tends to cause high traffic overhead.

In [3], the authors describe a Message Ferrying (MF) approach that delivers data efficiently in DTNs. They developed two variations of the MF scheme, node-initiated and ferry-initiated MF, depending on whether ferries or nodes initiate proactive movement. In the node-initiated MF scheme, ferries move around the deployed area according to known specific routes and communicate with other nodes they meet. However, in the ferry-initiated MF scheme, ferries move proactively to meet nodes.

In [5], the authors propose a message ferry route design algorithm that generates a ferry route in sparse MANETs where nodes have arbitrary movement. This method does not require any online collaboration between the ferry and the nodes, and does not disrupt the mobility of the nodes.

In [6], the authors study the problem of using multiple ferries to deliver messages in networks with stationary nodes and design ferry routes so that average message delay can be minimized. Multiple ferries offer the advantages of increasing system throughput and robustness to ferry failures. The authors present ferry route algorithms for a single ferry and multiple ferries, respectively.

In [9], the authors propose hybrid data routing in which the ferry only communicates with gateway nodes in each cluster, which aggregate traffic from nodes in a cluster and represent them when communicating with the ferry. While message ferrying is utilized among clusters, regular MANET routing is used within each cluster to exploit local connectivity.

All of the above ferries schemes use only ferries to deliver messages in DTNs. If the ferries move infrequently, message delivery delay would be very long.

3. Hybrid Ferry-Mobile Node Message Carrying

In our protocol, we consider a rural environment with a city and several rural villages as shown in Figure 1. We assume the villages are very far away from each other and each village network is ad hoc with mobile and stationary nodes. We assume that a stationary node in each village plays the role of a gateway to connect the different villages. Nodes in each village therefore can communicate directly within their radio range. However, if the destination nodes are in different networks, the nodes always transmit messages through their gateway. We use a MF to connect the villages to each other. The

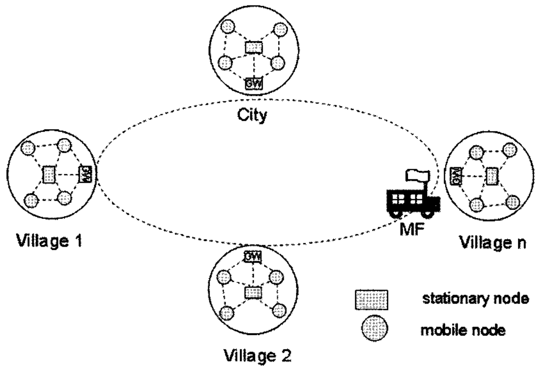
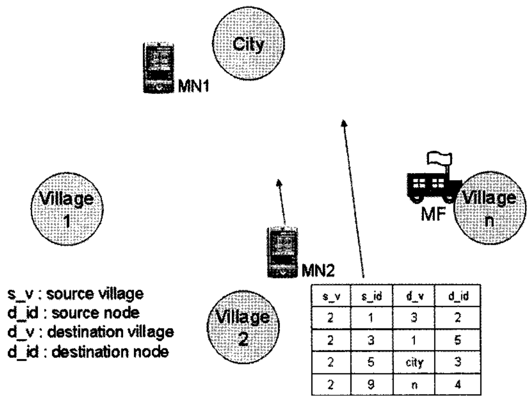


Figure 1 Network topology

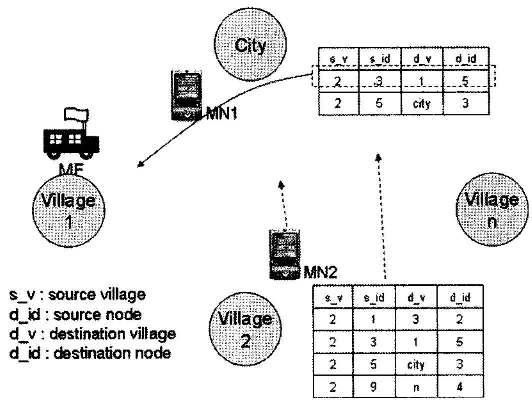
MF only has contact with gateways in the villages so that the ferry downloads and uploads messages for delivery. The mobile nodes from the rural villages can move only to the city, but not to other rural villages: a few mobile nodes in each village move in a day. However, mobile nodes from the city can move to any of the rural villages. After the visiting mobile nodes dwell for some time, they go back to their home villages within a day. We also assume the MF's buffer and the gateways' buffer can store infinite messages. The ferry follows a route from left to right once a day; the ferry starts from the city toward Village 1 in the morning, passes each village once a day, and arrives at the city from Village n in the evening.

In Figure 2, we assume that the ferry has just arrived at Village n in Figure 2(a), and at Village 1 in Figure 2(a), respectively. Also, MN1 whose home is Village 1 dwells in the city, the gateway of Village 2 stores four packets to transmit, and MN2 whose home is Village 2 is moving to the city.

First, we consider node mobility from a rural village to the city (ex. from Village 2 to City). This mobility includes mobile nodes visiting from a rural village to the city and going back from the city to the rural village. When a mobile node moves from a rural village to the city, we can have two cases: the ferry has already passed that village or the ferry has not passed yet. In the first case like Figure 2(a), any message from its gateway can not be delivered until the ferry arrives next day. Therefore, we make mobile nodes moving towards the city carry all messages. The reason is if there are



(a) Ferry has already passed



(b) Ferry has not passed

Figure 2 Protocol behavior

mobile nodes moving to other villages in the city, the nodes can deliver messages to the destination faster than delivering them by the ferry. In the second case like Figure 2(b), the message can be carried by the coming ferry that day. We make mobile nodes moving towards the city carry some messages so that the messages can arrive earlier than delivering them by the ferry. It is very clear that the message whose destination is the city arrives at the city earlier than when it is carried by the ferry. Unfortunately, if the destination of message is villages to the left of the current village, the ferry would carry the message the next day. However, if we moved messages to the city, the messages could be delivered to the destination village by a visited mobile node in the city. For example, when MN2 moves from Village 2 to the city in Figure 2(b), the node carries messages

```
If (a node moves from a rural village to the city) {
    If (MF already passed) Node carries all messages from its gateway to the city
    else {
        The node carries all messages whose destinations are both left side villages and the city
        if (a visited node meets any destination node of the carried messages in the city) Transmit
           messages to the destination node
    }
if (MF arrives at a village)  The gateway downloads messages whose destinations are its own village from
the MF and upload messages to the MF
if ( a node moves from the city to a rural) {
    The node carry only messages whose destinations are the same as the node's destination
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Figure 3 Algorithm of the proposed scheme

whose destinations are only the city and Village 1 i.e., the second and third packet from Village 2's gateway. Furthermore, if the message carried to the city meets its destination node, the message would be delivered to that node without delivering it to the village having the destination node.

Next, we consider ferry movement. The ferry operation is the same as other ferry behavior. When the ferry arrives at a village, the gateway of this village will download messages whose destination is that village. After that, the gateway will upload all messages to the ferry. When the ferry arrives at the city, all messages from the ferry are downloaded to the gateway, and then are delivered to their destinations. When the ferry starts from the city, its gateway uploads all data to the ferry.

Finally, we consider node mobility from the city to a rural village. This mobility is carried by city's mobile nodes or by the visiting mobile nodes going back to their home villages. In this mobility, the node carries all messages whose destination is the same as the node's destination village. For example, when MN1 goes back to its home village in Figure 2(b), the node carries the first packet (ex. (2, 3, 1, 5)) whose destination is Village 1 from the city's gateway.

Figure 3 shows the algorithm of our protocol described above.

4. Simulation

We simulated the performance of the proposed scheme using C language. Also we used SMPL (Simulation and Modeling Programming Language) [10] for random variable functions. Our simulation program included a number of functions. These included the traffic generation that first selected a source village and a source node randomly, and then chose a destination village and a destination node randomly. In addition, we considered the delivery of all messages from the source village to the destination village as well as the delivery of messages whose destination is the villages to the left. Then, we included the downloading and uploading of messages from the ferry and to the ferry, respectively. Finally, our program confirmed whether a ferry passes a particular point in the route.

Our results show that our scheme performed better than the ferry system, especially hybrid data routing [9], in terms of message delivery delay, throughput and resource usages while we vary the average message inter-arrival time from 10 to 50 minutes. We define the message delivery delay as the average delay between the time a message is generated and the time the message arrives at the destination. The throughput is defined as the average number of message delivered where the message delay is less than a day. To measure resource usages, we use the ferry buffer size defined as how many messages the ferry holds and the gateway buffer size defined as how many messages the gateway stores in its buffer, respectively.

We assume each village has 10 mobile nodes and 3 stationary nodes. Randomly generated mobile nodes of each village always go to the city, but mobile nodes of the city can visit any village. We assume it takes 2 hours for the ferry and mobile nodes to move between villages. The ferry follows the well-known route from left to right once a day; it starts from the city toward the rural villages at 8:00 and arrives back at the city at 18:00. The visiting mobile nodes dwell in their destination villages for a while, and then go back to their home villages within a day. The visiting time of nodes follows uniform distribution between 7:00 to 15:00. And the dwelling time follows the normal distribution where the mean is 3 and the standard deviation is 1. The frequency of nodes' movement follows the normal distribution where the mean is 2 or 3 and the standard deviation is 1.

All messages generated move to another village. The message size is 1 Kbyte and message inter-arrival time follows the exponential distribution. The ferry and nodes' buffer size is infinite, but we ignore the dwelling time in the villages, the message transmission and the propagation time. The simulation time is performed 5 times and we use the average values.

In Figure 4, we compare the ferry scheme [9] with our scheme with two results where the average number of node movements in a day is 2 and 3, respectively. As you can see, our scheme has much less delay time than the ferry scheme. We have a relative gain of about 38 - 43% in the message delay for our scheme, normal (2,1), over the ferry scheme. Moreover, normal (3,1) movement is much less delayed than the normal (2,1). That is because normal (3,1) makes more mobile nodes carry messages than that of normal (2,1). However, the message load does not affect the delay time. As we assumed, the ferry's and nodes' buffers are infinite, the ferry and moving nodes always carry

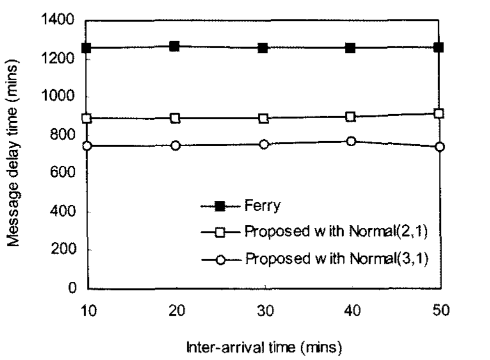

Figure 4 Message delivery delay

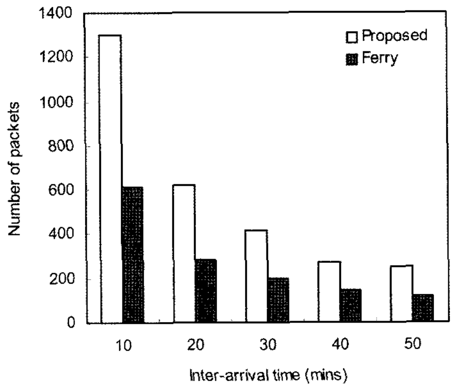

Figure 5 Throughput

all messages waiting to be delivered.

In Figure 5, you can see that the throughput of the proposed scheme is much better than that of the ferry scheme. The most significant gain is about 120%, but the least gain is about 83%. This is because messages are able to be carried by both ferries and visiting nodes in our scheme. As the inter-arrival time increases, the throughput conversely decreases, because the number of generated message also decreases. This throughput affects end-to-end message delay. Thus, the better throughput results in less delay.

Figures 6 and 7 show the average buffer size of the ferry and gateway respectively. As you can see above, our scheme needs less buffer compared to the ferry scheme. Messages are stored in the gateway's buffer for delivery to another village. After downloading messages from the gateways, the ferry stores the messages in its buffer to carry them. As moving nodes can deliver messages in

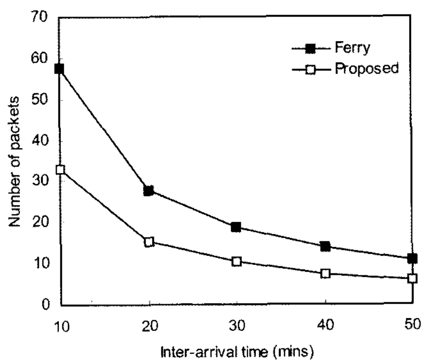

Figure 6 The average ferry's buffer

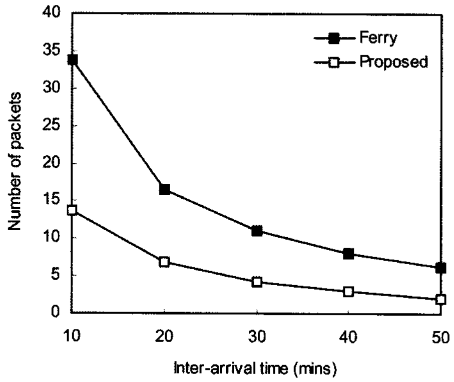

Figure 7 The average gateway's buffer

our scheme, the gateways are not required to store those messages delivered by the moving nodes. This causes the ferry to download fewer messages from the gateways. We have a relative gain of about 74 - 91% in the ferry buffer size for our scheme over the ferry scheme as well as a gain of about 141 - 200% in the gateway buffer size for our scheme over the ferry scheme. In both Figures, as the inter-arrival time increases, the buffer size also decreases. That is because the number of messages to be delivered also decreases.

5. Conclusions

In village networks, mobile nodes would move to different villages as people visit hospitals, the post office and shopping malls in other villages. In the traditional MF schemes, only ferries deliver messages to connected partitioned networks. In this paper, however, we have presented the hybrid message carrying scheme that makes both periodic ferries and irregular moving nodes carry messages between the partitioned networks.

We simulated the behavior of the proposed scheme, and compared it with ferry only carrying using different metrics: message delivery delay, throughput, node buffer and ferry buffer usages. In the results, we achieved less message delivery delay, a higher number of delivered messages and less resource use, especially buffer to store messages than was found in the ferry only carrying scheme. When two mobile nodes in each village move to the city, we had a relative gain of about 38 - 43% for the message delivery delay, 83 - 120% for the throughput, 74 - 91% for the ferry buffer usage and 141 - 200% for the gateway buffer usage, respectively.

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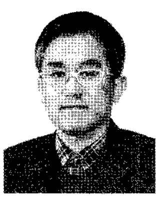

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