Novel Scheme for the Distribution of Flyers Using a Real Movement Model for DTNs

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Abstract In delay tolerant networks (DTNs), simulations used to verify the performance of a routing algorithm usually employ a mobility model, either trace or synthetic. Trace models record the actual movement of individuals in the real world; however, obtaining data can be difficult. Synthetic models use mathematical modelling, which eliminates the need to obtain data from participants; however, this means that the results are not necessarily representative of the actual movement of individuals. This study collected information related to the movement of university students using a specially designed APP featuring location aware and behavior aware functionality. This APP tracks the movement of students in a campus environment and then exports the data for simulation. We also developed a method for the distribution of flyers only to individuals who express an interest in the content of that particular message who can then forward the flyers to others. Simulation results demonstrate that the proposed method is able to enhance the successful delivery ratio while reducing delivery overhead and thereby improve the dissemination of data on campus.

1 Introduction

Delay tolerant networks are sparse mobile wireless networks without a fixed infrastructure. As a result, network connections are unstable, nodes move in unpredictable directions, and establishing an end-to-end route for connections can be difficult because communication between nodes tends to be intermittent.

Mobility models are generally classified into two types: trace and synthetic. Trace models, such as Infocom 06 trace data [1], Cambridge traces data [2] and MIT Reality trace [3], record the movement of individuals in the real world.

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Unfortunately, the collection of the data used in trace models is not easy. Synthetic models, such as the random walk mobility model and random waypoint mobility model [4], are based on mathematical models.

Considerable research has also been conducted on the dissemination of messages using DTNs. Most these studies rely on the contact utility of nodes to determine whether messages should be forwarded to another node close to the destination. Unfortunately, this kind of distribution is considered a form of spam, is irritating and greatly increases delivery overhead. This study proposes a real movement model to overcome the problem of message flooding and reduce distribution costs.

We conducted an experiment based on MIT Reality [3] for the collection of data related to the movement of university students using a specially designed Android App, called NCCU Trace Data. We sought to obtain trace data that includes a diversity of users with the aim of obtaining results that are more generalizable than that achieved using previous schemes [1–3]. The mobility trace data can then be exported to the ONE Simulator to verify the effectiveness of the routing algorithms.

We also developed a scheme for the distribution of flyers suitable for an actual campus environment. In the proposed scheme, referred to as “Direct Contact Distribute”, students send flyers only to target students that may be interested in receiving the flyer. These same students can then forward the flyers to others using a scheme referred to as InDirect Contact Distribute. Finally, we used the proposed NCCU Trace Data as a mobility model with which to evaluate the effectiveness of the flyer distribution scheme. Simulation results demonstrate that compared with other routing algorithms, the proposed method is able to enhance the successful delivery ratio while reducing delivery overhead.

2 Related Work

This study focused on two topics: (1) mobility models and (2) efficient routing schemes for DTNs.

(A) **Mobility models**

Mobility models can be classified into two types: (1) trace and (2) synthetic.

(1) Trace: Previous studies on the collection of trace data include MIT reality trace data [3], Cambridge trace data [2] and Infocom 06 trace data [1]. MIT Reality trace data was obtained by deploying 100 NOKIA cellular phones to users working in a single building at MIT over a period of nine months. Infocom 06 trace data was obtained from 78 users attending a conference over a period of four days. Cambridge trace data was obtained from fifty-four users living in the city of Cambridge.

(2) Synthetic: Each node moves independently from the others [4]. The random walk mobility model is based on random directions and speeds. The random waypoint mobility model is similar; however, the duration in which the node remains in a given location is longer.

Previous studies [1–3] are limited to activity within a single building, wherein participants frequently encounter one another. In this study, we investigated mobility models with a focus on individuals spread over a university campus, thereby more closely approximating a real world environment. Student volunteers for our experiment were recruited at random from all departments at Chengchi University to ensure that students would appear in every corner of the campus, rather than only one building. This helps to ensure that the results are more generalizable.

(B) **Efficient routing scheme for DTNs**

In Epidemic routing [5], nodes replicate messages and indiscriminately forward them to a single destination. In cases where a node already has a copy of the message, the message is not forwarded.

Spray and wait routing [6] proceeds through two phases: (1) spray and (2) wait. The source node initially sets L copies of messages. In the spray phase, the source node is given a strict upper bound regarding the number of copies of each message that it is allowed to introduce into the network. Half of the messages are forwarded to another node and when only one message is remaining, it is not forwarded and enters the wait phase. In the wait phase, the last message copy is forwarded to the final destination.

PRoPHET routing [7] uses previous encounters with other nodes to determine which node has a higher probability of contacting the destination node and then uses this node for the delivery of that particular information.

The PeopleRank scheme [8] uses information related to a social network to identify the most popular node, which is selected to actually transmit the message.

Most routing algorithms base their message forwarding decisions on the probability of encounters between nodes. They do not take into account whether the receiver is actually interested in receiving that particular information. In this study, we employ a message forwarding strategy in which messages are delivered only to individual nodes that express an interest in the content of the message. We then used NCCU Trace Data to enhance the efficiency of the system.

3 Proposed Approach

Consider a campus environment, in which activities are advertised through the distribution of flyers via a DTN. Our research was divided into two parts: (A) the collection of data related to the mobility of students within a campus; (B) a scheme for the dissemination of messages based on the stated interest of the recipients in order to overcome the difficulties of message flooding problem and excessive traffic.

(A) **Data collection**

Based on previous works [1–3], we designed an Android App with location-aware and behavior-aware functionality referred to as “NCCU Trace Data” for the

Table 1 Data obtained in movement tracing experiment

Experiment dates	2014/12/17–2014/12/31
Number of volunteers	115
Number of departments	29
School days	From monday to friday
Campus size	3764 m × 3420 m

collection of daily trace data from university students. We recorded the movements of 115 university students while living on campus over a period of two weeks. The resulting data are presented in Table 1.

NCCU Trace Data was used to collect data related to the location of the user, Bluetooth devices, the usage of applications, and Wi-Fi access points, as shown in Fig. 1. Data was collected only while participants were present on campus.

NCCU Trace Data records the data as follows:

1. Location
   The positioning of users is determined using the global positioning system (GPS) as well as Wi-Fi and 3G GPS when users are in buildings.
2. Usage of Android Applications on mobile phones
   The frequency and duration spent using applications, such as Google Maps and Facebook, are recorded for the characterization of usage behavior.
3. Bluetooth devices
   We also recorded how frequently students connect with other devices via Bluetooth as a proxy for the relationships among students.
4. Wi-Fi access points
   NCCU Trace Data records how many Wi-Fi access points are proximal to a given destination by using information, such as SSID, MAC addresses, and RSSI.

Fig. 1 Screenshot showing NCCU trace data

To reduce battery consumption, the data collection APP is triggered only every ten minutes. The App runs in the background to prevent interference with the use of other applications.

We used questionnaires for the collection of personal information from users, including age, sex, grade, major, Facebook ID, personal interests, and Facebook usage behavior. Personal interests are classified into five categories: academic, athletic, artistic, community, and social activities. Personal interests were rated using a Lickert-type scale from 1 (strongly dislike) to 5 (strongly like). Summed scores are converted into standardized scores ranging from 0 to 1, with higher scores representing stronger interest. We also investigate the usage characteristics of Facebook including frequency, duration, and specific tasks, such posting articles, sharing video links, and sending private messages.

These experiments involved the collection of personal information; therefore, prior written consent was obtained from all users and all personal information was encrypted prior to use.

(B) **Targeted flyer distribution scheme**

Every day, numerous flyers are published and distributed to students on campus. Unfortunately, many students are annoyed by flyers that do not interest them. Thus, we developed a novel scheme for the distribution of flyers based on the personal interests of students.

In the proposed scheme, there are two situations in which students forward flyers to other students:

1. Direct Contact Distribution
   When student S_A, who has a flyer about a sporting event, meets student S_B, they first exchange hobby-related information. If student S_B is interested in sports, then S_A delivers the flyer to S_B.
2. InDirect Contact Distribution
   In some cases, student S_A tries to send a flyer to student S_B; however, S_B has no interest in sports. Nonetheless, S_B may is linked to student S_C who is interested in sports. In such cases, student S_A is able to deliver the flyer to Student S_C via Student S_B.

To determine whether a student is interested in a particular type of flyer, we employed m-dimensional cosine similarity for the calculation of attribute similarity between students and flyers. When student come into contact with other students, they exchange interest-related data and store it within a matrix. In this study, we used questionnaires to collect information related to the interests of 115 volunteers, which was then imported into a simulation program for the calculation of similarity between personal interests and flyers.

Interests are divided into *community* (I_1), *academics* (I_2), *athletics* (I_3), *arts* (I_4), and *social activities* (I_5) as well as into five preference levels: strongly like, like, neutral, dislike, strongly dislike. For example, student S_A likes community, strongly likes academics, strongly dislikes athletics, dislikes arts, and likes social activities.

These are represented using the following values: 0.75, 1, 0, 0.25, and 1, and are then shared with contacts.

When, student S_A, who has k number of flyers to distribute, meets student S_B, m-dimensional cosine similarity is used to calculate the similarity of attributes between the personal interests expressed by student S_B and the flyers that student is holding F_K, as follows:

$$\mathrm{Cos}(S_B(I), F_k(I)) = \frac{S_B(I) \cdot F_k(I)}{\|S_B(I)\| \cdot \|F_k(I)\|} = \frac{\sum S_B(I) \times \sum_{k=1}^{n} F_k(I)}{\sqrt{\sum (S_B(I))^2 \times \sum_{k=1}^{n} (F_k(I))^2}} \tag{1}$$

The resulting similarity ranges from 0 to 1. A result of 0 indicates that the individual is not interested in flyer F_K. A result of 1 indicates that the individual is very interested in the flyer. Intermediate values indicate moderate levels of interest. The calculation of similarity enables the distribution of the flyer F_K only to students who are genuinely interested in it.

This algorithm is outlined in the following:

Algorithm Used in Flyer Distribute Scheme

Input: Simulation_Finished_Time SFT , x-th Students' Interest attribute $S_x(I)$, k-th Flyer attribute $F_k(I)$
Output: Distribute Flyer
Meta_Data: {list of Student S_x's contacts S_x_meetlist, Flyers' index F_k }

Interest threshold = 0.75

```
While(SFT !=System_current_time){
        If (Connect_Student S_B)
             Exchange_Meta_Data();
             Compute Cos(S_B(I), F_k(I));

                   If (Cos(S_B(I), F_k(I)) > Interest threshold)
               Delivery one copy to S_B
                              // Direct Contact Spread
                   EndIf

                   Else
                   For(int x =0 ; x < x_meetlist.size(); x++)
               Compute Cos(S_x(I), F_k(I));

                      If (Cos(S_x(I), F_k(I)) > Interest threshold)
                  Forwarding one copy to Student S_B
                               // InDirect Contact Spread
                      EndIf
              EndFor
    Increase(current_time);
        EndIf
   EndWhile
```

4 Simulation Results

Patterns of movement affect the performance of routing protocols in DTNs. Thus, we compared the performance of the proposed scheme with that of other DTN routing protocols, including Spray and Wait [6], Epidemic routing [5] and PROPHET [7]. In The ONE simulator [9] we used NCCU Trace Data as a mobility model to represent the actual movement of students on the campus throughout the week. We used the following performance metrics to measure success in the delivery of flyers:

(1) Deliver Success Ratio: the rate of each flyer being successfully delivered to multiple destinations
(2) Delivery Delay: the average delay in the delivery of flyers
(3) Delivery Overhead: the average number of relays required for the delivery of flyers

(A) **Simulation methods**

In the following, we compare the performance of the proposed scheme with existing routing schemes:

(1) Epidemic [5]: Students replicate flyers and forward them to all students with whom they are in contact (including all new contacts) except those who already have a copy.
(2) Spray and Wait [6]: The source node initially sets L copies of messages. In the spray phase, the source node is given a strict upper bound regarding the number of copies of each message that it is allowed to introduce into the network. Half of the messages are forwarded to another node and when only one message is remaining, it is not forwarded and enters the wait phase. In the wait phase, the last message copy is forwarded to the final destination.
(3) PRoPHET [7]: This approach uses previous encounters with other nodes to determine which node has a higher probability of contacting the destination node and then uses this node for the delivery of that particular information. This method is well suited to situations involving multiple destinations.

(B) **Simulation**

The proposed scheme was implemented using The ONE Simulator (Opportunistic Network Environment Simulator) [9]. Mobility models can be imported into the ONE Simulator by converting them into movement trajectories in order to provide actual trace data for simulation. We ran simulations of the 115 students for a period of 86,400 s, which represents a day in the life of a student. The coverage of the map is 3764 m × 3420 m, encompassing the main area of the campus. The novelty of this mobility model is its ability to model the movement of students as they proceed to classes or extracurricular activities. We considered the fact that flyers are not generated randomly, but rather, they are based on the message sending habits of the students. Our previous questionnaire asked students how often they send dynamic or

Table 2 Simulation parameters

Simulation times	86,400 s
Area	3764 m × 3420 m
Radio range	10 m
Flyer size	500 kB–1 MB
Interval of message creation	The student behavior
Data rate	2 Mbps
Buffer size	500 MB
Time to live	18,000 s

private messages on Facebook. We used the results of the questionnaire to give us an indication of the time intervals involved in the generation of messages. The simulation parameters are listed as Table 2.

(C) **Simulation result**

The original version of the Epidemic, Spray and Wait and PRoPHET routing schemes include only a single destination. Thus, to ensure a fair comparison, we modified the flyer to enable delivery to multiple destinations in a DTN.

As shown in Fig. 2, the performance of the proposed scheme is similar to that of the Epidemic routing scheme and clearly outperformed Spray and Wait and PRoPHET with regard to delivery success ratio. Our objective was to eliminate instances of scanning by limiting delivery only to students with an expressed interest in the content of the messages. Thus, unlike Epidemic routing, which floods every student that it meets with flyers, the proposed scheme enables the selection of students to whom specific flyers should be directed, thereby decreasing network

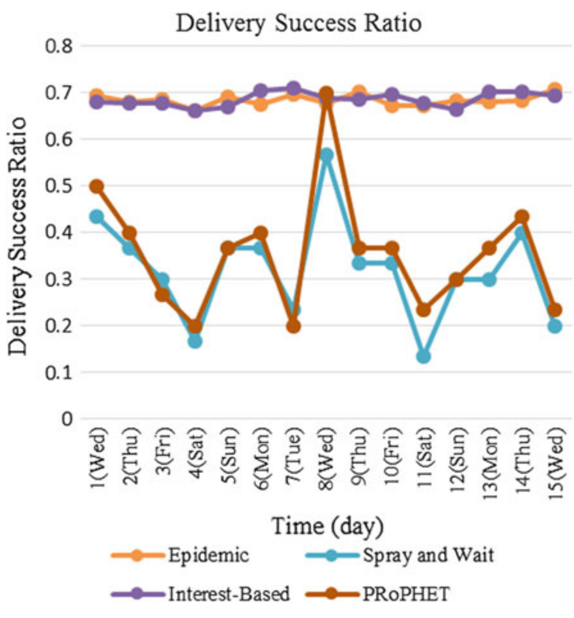


Fig. 2 Delivery success ratio

overhead. In addition, the performance of the Spray and Wait and PRoPHET routing schemes dropped noticeably on Saturdays, because the stored movement patterns do not match the actual movement of students on weekends. On weekends, few students encounter one another on campus, which makes it difficult to deliver or forward flyers. The Spray and Wait routing scheme limits the number of flyer copies that can be forwarded and fails to take into account the specific attributes of the flyers. Thus, in the spray phase, the flyers are forwarded indiscriminately and in the wait phase, flyers cannot be delivered. Eventually, the lifespan of the flyer is exceeded, and which point it is dropped. The PRoPHET routing scheme uses previous contact with students to identify individuals with the highest probability of reaching the contact destination. As with the Spray and Wait approach, when there are few students on campus, many of the flyers are dropped before they can be delivered.

As shown in Fig. 3, the Spray and Wait routing scheme resulted in the lowest overhead ratio because this method limits the number of copies that can be made of each flyer, such that copies are not always forwarded to all of the students who are contacted. Compare this to the Epidemic routing scheme in which an unlimited number of copies of each flyer can be made. In Epidemic routing scheme, students replicate flyers and forward them to all students with whom they are in contact (including all new contacts), except those who already have a copy. This approach increases the number of relays and subsequently in delivery overhead.

The PRoPHET routing scheme forwards flyers in accordance with the movement of students, which results in heavy delivery overhead on school days, as shown in Fig. 3. The proposed scheme distributes flyers only to students with an expressed

Fig. 3 Overhead

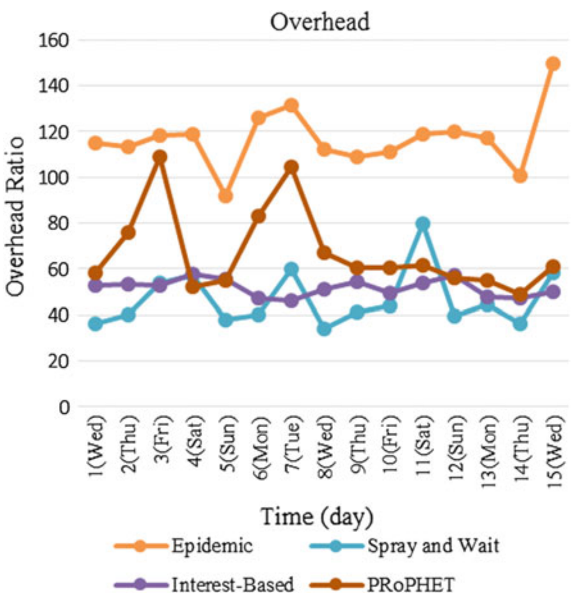
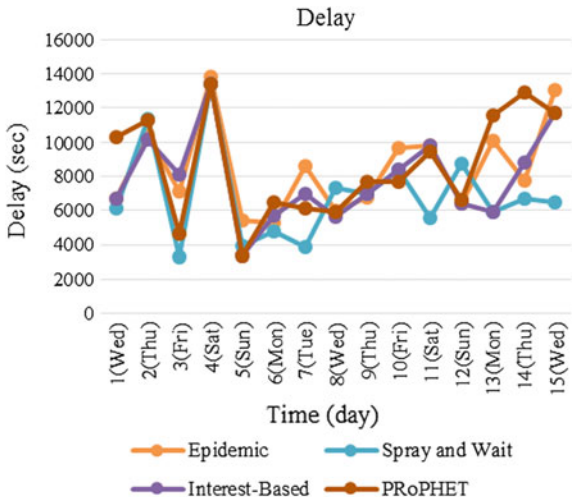


Fig. 4 Delivery delay



interest in the topic of the flyer, thereby reducing the number of unnecessary relays and decreasing delivery overhead. The proposed method reduces delivery overhead to a level far below that of Epidemic and PRoPHET routing schemes

As shown in Fig. 4, all of the routing schemes have similar performance with regard to delivery delay. Particularly on Saturdays, all of the routing schemes are prone to serious delivery delays of approximately 13,000 s, due to a lack of students on campus.

The above simulation results demonstrate that the proposed NCCU Trace data can improve the performance of routing schemes on DTNs by taking into account the movement of potential targets. The efficacy of this approach was verified through a comparison with four existing routing schemes, which have particularly poor performance on weekends when students are not on campus. Our simulation results clearly demonstrate the superior performance of the proposed scheme with regard to delivery success ratio and reducing delivery overhead.

5 Conclusions and Future Work

In this paper, we developed a scheme for the distribution of flyers based on the topic of the flyer and the stated preferences of potential targets. We then developed an Android App with location-aware and behavior-aware functionality, referred to as NCCU Trace Data, to record the movement of university students on campus for use as a mobility model in simulations. Simulation results demonstrate the efficacy of the mobility model in enhancing the successful delivery ratio beyond that achieved using the PRoPHET and Spray and Wait routing schemes with a delivery overhead ratio far exceeding that of Epidemic routing.

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