Journal of Computers Vol. 28, No. 3, 2017, pp. 132-146
doi:10.3966/199115592017062803011

A Community-Based Message Transmission Scheme for High Efficient in Opportunistic Networks

Dong-liang Xu[1], and Ji-kai Yang[2]

[1] Key Laboratory of Mobile Communication Technology,
Chongqing University of Posts and Telecommunications,
Chongqing, 400065, China
1251523004@qq.com

[2] Key Laboratory of Mobile Communication Technology,
Chongqing University of Posts and Telecommunications,
Chongqing, 400065, China
420374294@qq.com

Received 30 May 2016; Revised 06 January 2017; Accepted 06 January 2017

Abstract. In order to address the problems that message-distributed task are backlogged by nodes in the inner community, active nodes are blindly selected, the message transmit disorderly and message storage redundancy in the Community-based Message Transmission Scheme in Opportunistic Social Networks (OSNCMTS). We proposed a Community-Based Message Transmission Scheme for High-Efficient in opportunistic networks (HECMTS) in this paper. In HECMTS, firstly communities are divided by EO algorithm and community matrices are distributed to nodes. Secondly the copies of message are assigned through the success rate of message and the community matrices to destination nodes. The active nodes' information is collected through the active nodes' back and forth in different communities. Some nodes are selected to finish message transmitting between communities. Finally, Message-Carried Nodes (MCN) transmit message according to the success rate that Forwarding Nodes (FN) carry message to destination. In addition, the MCN delete obsolete message through the success rate of message reaching destination and the time of caching message at the same time. The simulation results show that routing overhead and the average end-to-end delay in HECMTS is decreased by at least 19% and 16% compared with OSNCMTS.

Keywords: community matrix, community, message-carried nodes, opportunistic networks, social nodes

1 Introduction

With the emergence of a large number of short distance communication interface devices, researchers began to focus on how to exploit the communication opportunities which devices move have brought to make a network, and then put forward the concept of opportunistic networks [1-2]. At present, there is no uniform definition of opportunistic networks, general default for opportunistic networks is a kind of do not have complete link between the source node and the destination node, which is a self-organization network that utilizes the mobile node contact opportunity to achieve data communications [3]0.

There are some nodes which are carried by human and other mobile vehicles in the opportunistic network, such as the portable intelligent mobile phone, PDA, etc. Because there is a certain dependency of social relations between carriers, relatively stable, and therefore these nodes in the opportunistic network periodically aggregation and dispersion [4]0. The data transmission success rate and reduce the time delay of data transmission can be improved by exploiting the aggregation and dispersion phenomenon of these nodes [5]0.

2 Introduction

Existing classical opportunistic network routing algorithm such as Epidemic [6]0, Prophet [7]0, Spray and Wait (SW) [8]0, Context-Aware Routing (CAR) [9]0 and other routing protocols simply use a copy of the forwarding, without consideration of the social nature of mobility nodes, so it is not suitable for opportunistic networks which nodes have social nature. Based on them, researchers have proposed a variety of routing algorithms based on community opportunistic networks. Reference [10]0 proposed Encounter and Distance based Routing (EDR) algorithm which utilizes the forward parameter to determine the next hop selection. The forward parameter is relying on the value of encounters and distance of neighbor nodes of source or intermediate node to destination. So it calculated by taking into account the number of encounters and the distance of each node in the network with respect to a particular destination. The result is showing the superiority of EDR over the History-based Prediction for Routing (HBPR) [11]0 protocol in terms of hop count, and average latency. However, the EDR algorithm dose not combines with game theoretical to calculate the delivery probability, so the average delay is not better. Reference [12]0 proposed community construction algorithm based on radiation propagation in opportunistic network. The algorithm based on the radiation calculation and diffusion model of the core node. The betweenness centrality of nodes obtained by calculation radiation between nodes and the community around a core node was constructed based on it. The message can be forwarded to the destination node along the shortest path, after entering the destination node's radiation propagation community, thus gaining high packet forwarding efficiency. However, the algorithm has a large overhead in construct community. Reference [13]0 proposed a novel transitivity-based multiple-copy transmission scheme. The scheme calculates the delivery probability according to the historical temporal and spatial information of node, and applies it to a novel spray and transfer strategy. The node smartly chooses the next hop and builds up an optimal path to the destination, enhancing the transmission efficiency. But there has a problem that the number of copies are blindly selected in this scheme. Reference [14]0 proposed a message transmission label strategy based on social structure, which creates labels for each node, on behalf of their respective communities. If the two nodes have the same label, indicating that the two nodes belong to the same community. In the label algorithm for transmitting message, the message can only be transmitted to the destination or other nodes have the same label with the destination, while ignoring the probability of other nodes that carry the message encountered the destination, resulting in message transmission delay. Reference [15]0 proposed a Rap-Bubble, which is based on the community message transmission algorithm in the delay tolerant network. The algorithm is designed for each node of two kinds of ranking table: global ranking table and local ranking table, they record the distribution of nodes in the entire network and the activity level rankings of the community. The source node transmits the message to the top of the node in the global ranking table when there have message to be transmitted, until it encounters intermediate nodes within the same community with the destination and until it encounters the destination. Since the algorithm uses a single copy of the transmission of messages, that the message can only be transmitted between one to one node. Compared with multi copy messages transmission, Bubble Rap algorithm message transmission delay is large. Reference [16]0 proposed a community-based message transmission scheme in opportunistic social networks (CMTS).The scheme according to the contact frequency of nodes periodically divided community of social networks. Within the community, the "Spray and Wait + Prophet" algorithm is used to design the message transmission mechanism, and active nodes forward the message mechanism is used in inter-communal. The proposed algorithm has been improved in terms of message transmission delay and message transmission success rate compared to the classical opportunistic network routing algorithm. However, the algorithm ignores the nodes with different activity. Some messages distribution task may backlog on a node, which can not be transmitted and resulting in the delay of message transmission. Meanwhile, MCN neglects the probability that the FN can carry the message to the destination in the limited encounter time. A message satisfies the condition that without selection to be transmitted to the FN, which leads to some message that have a greater probability of reaching the destination miss the opportunity to transmission and increased the message transmission delay. The message will be forwarded to all active nodes in the source community if there is no active node in the source community that can arrive at the destination community when the message transmission between the community, which is forwarding blindness and causes the message over head waste. In view of the defects in the routing algorithm above-mentioned, a

Community-Based Message Transmission Scheme for High Efficient in opportunistic networks (HECMTS) is proposed in this paper.

3 Network Model and Problem Description

3.1 Network Model

In order to facilitate the description of the following message transmission strategy as well as the theoretical analysis and verification, network model was defined based on community in this paper.

Definition 1: Network Topology. Since the mobile nodes have a certain social nature and in order to make this kind of social performance in the network topology, the network topology is defined as a connected graph containing nodes and links as follows:

$$G = (V,E) \quad \textbf{(1)}$$

Where *G* is the network topology, *V* is the set of nodes in the network topology; *E* is the set of links between nodes. If there are links between the nodes, there is a social nature between the nodes, otherwise there is no.

Definition 2: Node Model. In order to distinguish between different nodes and whether the nodes belong to the same society, the node model is defined as a set containing the node number and the community number as follows:

$$e_i = \left(S_i, Buffer_i, C_i\right) \quad \textbf{(2)}$$

Where S_i is node number, C_i is community number, $Buffer_i$ is node cache space.

Definition 3: Community Matrix. A correlation matrix is generated based on the history of the encounter between the nodes and community is divided according to the correlation matrix in the Extremal Optimization (EO) algorithm [17]. The community matrix records the social relations among the nodes in the community. In this paper, the sub matrix of the correlation matrix of each community is defined as the community matrix. In the community matrix, if the value of the two nodes is 1, it indicates that the node has a social relationship, otherwise it is not.

Definition 4: Social Node. Social node is defined which some nodes often associated with the source community and other communities in this paper.

Definition 5: Social values. In order to measure the closeness between social nodes and other communities, the calculation formulas of social values are introduced in this paper. Social values are related to the number of times and the time interval for a social node to other communities.

$$W = \frac{Count}{\sum_{i=1}^{Count-1} T_{i+1} - T_i}(Count - 1) \quad \textbf{(3)}$$

Where *W* is a social value, *Count* is the number of times that social node to go to the community. T_{i+1}-T_i is time interval that a social node to other communities.

Definition 6: Social Node Regression. In this paper, the mobile features of social nodes that from the source community and other communities, between the s and the source community and other communities defined as the regression of social node.

3.2 Community Division

In the community network, each node maintains a probability vector V = (P_1, P_2, P_3... P_n), the probability of node encountered every node in the network was record in this vector. The method for calculating the probability reference Prophet algorithm. Within the prescribed warm-up time, each node gathers the probability information which node encounters its own. After the warm-up time exceeded, EO algorithm statistical probability information of all nodes gathered and form a probability matrix. EO algorithm set the probability that greater than the threshold value P_{th} is 1, otherwise it is set to 0 which as shown in Fig. 1 and Fig. 2. Fig. 1 is the probability matrix, and Fig. 2 is the value matrix that the probability value transformed. Then the EO algorithm divides the community for nodes and allocates a label value for each community., label values and community matrix (such as the dotted circle in Fig. 2) of nodes in the community was sent to the in this community by the EO algorithm after the the community division complete. According to the value matrix two communities C_1 and C_2 were divided as show in Fig. 3. The C_1 community contains node N_1, N_2, N_3, C_2 community contains node N_4, N_5, N_6.

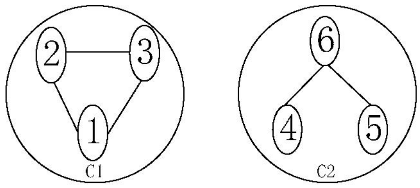

Fig. 1. Community division

NODE	N_1	N_2	N_3	N_4	N_5	N_6
N_1	∞	0.95	0.86	0.32	0.28	0.16
N_2	0.95	∞	0.74	0.18	0.39	0.47
N_3	0.86	0.74	∞	0.25	0.37	0.18
N_4	0.32	0.18	0.25	∞	0.34	0.89
N_5	0.28	0.39	0.37	0.34	∞	0.76
N_6	0.16	0.47	0.18	0.89	0.76	∞

Fig. 2. Probability matrix

NODE	N_1	N_2	N_3	N_4	N_5	N_6
N_1	∞	1	1	0	0	0
N_2	1	∞	1	0	0	0
N_3	1	1	∞	0	0	0
N_4	0	0	0	∞	0	1
N_5	0	0	0	0	∞	1
N_6	0	0	0	1	1	∞

Fig. 3. Value matrix

Considering the nodes in the community, the node's life habits and interests will change with the time, periodic division of the community in this paper.

3.3 Problem Description

Basic ideas of OSNCMTS algorithm: Using multiple copies of the transmission, when the transmission of messages within the community the source node first to estimate the number of copies of the message of L that injected into the community, and then the source node generates a message and changes to the MCN. When the L is greater than 1, the MCN transmits the message to the encounter node that does not contain the message and the copy number of the message is $L/2$, the copy number of the message of the encounter node is $L/2$ too. When L is 1 the MCN transmits the message to the node which has higher probability to encounter the destination and delete messages in memory. When a message is transmitted between the communities the source node generates a message and changes to the MCN. If the source community contains an active node to reach the destination community, the MCN transmits the message to the active node. If the source community does not have an active node to reach the destination community, the MCN transmits the message to the active node within other community. If the source community does not contain an active node to reach other community, the MCN will carry the message until encounter the destination.

Through in-depth research we found that in OSNCMTS algorithm there are 3 problems:

(1) The MCN within the community carried the number of copies of the L is greater than 1, the MCN does not take into account the activity of the encounter node and the relationship between the destination. which result the number of message copies accumulated in the encounter nodes that reduce the speed of message distribution and increase the transmission delay.

(2) The number of copies of the L within the community is greater than 1 and the MCN transmitted the message, the MCN just random transmissions the message meet the conditions. While ignoring the probability of FN carries the message to the destination, which leading to some messages have a greater probability reaches the destination misses this opportunity and increases the transmission delay.

(3) The message is transmitted to all active nodes within the source community when the source community does not exist to reach the active nodes of the destination community. The message will carry to other communities through those active nodes, and then find the active nodes in other communities that can reach the destination community. However, this operation does not consider whether other communities have active nodes to reach the destination community, so this kind of blind operation will lead to the waste of message overhead.

In order to solve the above problems, HECMTS routing algorithm is proposed in this paper.

4 HECMTS Algorithm Principle

In HECMTS algorithm, 4 new mechanisms are designed in this paper: the distribution of message distributing tasks mechanism within the community, the message transmission mechanism within the community, the message transmission mechanism between the community and the message storage mechanism.

4.1 Distribution of Message Distributing Tasks Mechanism

This new mechanism refers to nodes within the community according to the community matrix and node probability distribution of message distributing tasks. The main idea of this mechanism is that the MCN *m* encounters the node *n* which dose not carries the same message, the node *m* gets the probability that the node *n* reaches the destination and calculates the possible number of methods for the node *n* reaches the destination according to the community matrix. Then use the formula 4 to calculate the number of messages allocated to the node *n*, the node *m* distributes the message task to the node *n*. Simultaneously the node *m* distributes copies reduce the L_i.

$$L_i = \frac{N_i}{P_i} \quad \textbf{(4)}$$

Where L_i is the distribution task assigned to the node *i*, N_i is the most possible number of methods of the FN *i* reach to the destination, P_i is the probability of FN *i* to the destination.

The operation of the mechanism is divided into the following 3 steps, the flow chart is shown in Fig. 4:

Step 1. Initialization stage. Source node calculates the total distribution number L of the message within the community according to Spray and Wait algorithm, and then turn to the MCN.

$$(H_N^3 - \frac{6}{5})L^3 + (H_N^2 - \frac{\pi^2}{6})L^2 + \left[\alpha + \frac{2N-1}{N(N-1)}\right]L = \frac{N}{N-1} \quad \textbf{(5)}$$

L is the number of message copies, $H_n^r = \sum_{i=1}^{n} \frac{1}{i^r}$ is the sequence of r of the *n-th* harmonic function, N

represents the total number of nodes in the community.

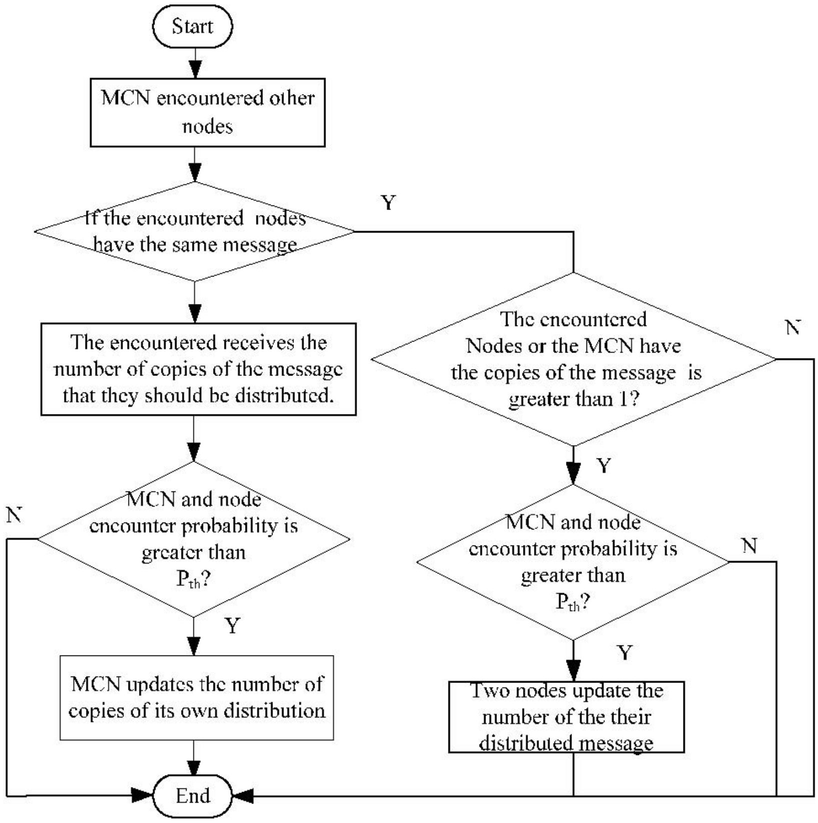

Fig. 4. Flow chart of distribution mechanism in community

Step 2. Distribution stage. The MCN *m* encountered the node *n* which does not carrying that message. If the node m has the message copies of is greater than 1, the m node with the center of the FN in the community matrix and excluding nodes who has already contains this message and calculating the possible number of methods that the node *n* to the destination through other FNs. Then according to formula (4) calculate the number of messages to be distributed and pass the message copies to the node *n*. If the two node encounter probability is greater than the threshold value P_{th}, the node *m* reduces the number of copies, otherwise the message number is unchanged. If the number of the message copies of the node m is 1, then judge whether the probability of reaching the destination of the n node is greater than that of the *m* node, if it is then transmit to the *n* node, otherwise it will not transmit.

Step 3. Distribution task offset stage. If the two nodes with the same message encountered and one of nodes' message copies is not 1 and the two node encounter probability is greater than the threshold value P_{th}, which indicate that two nodes have been obtained forwarding task from other nodes.

4.2 The Message Transmission Mechanism within the Community

The main idea of this mechanism is that the MCN encountered the FN, selecting qualified message according to the information of the FN. From high to low order for those message according to the success rate of size and give priority to the high success rate of the node.

The operation of the mechanism is divided into the following 3 steps. The flow chart is shown in Fig. 5:

Step 1. The MCN and FN exchanged each others experience with other nodes probability table when they are encountered.

Step 2. The MCN selects the FN according to the probability table, which without carry that message and have a greater probability to transmit that message to the destination. And arranged the success rate the size of the order according to FN carries the message to the destination.

Step 3. The MCNs transmit those messages to the FNs as far as possible in the limited encountered time.

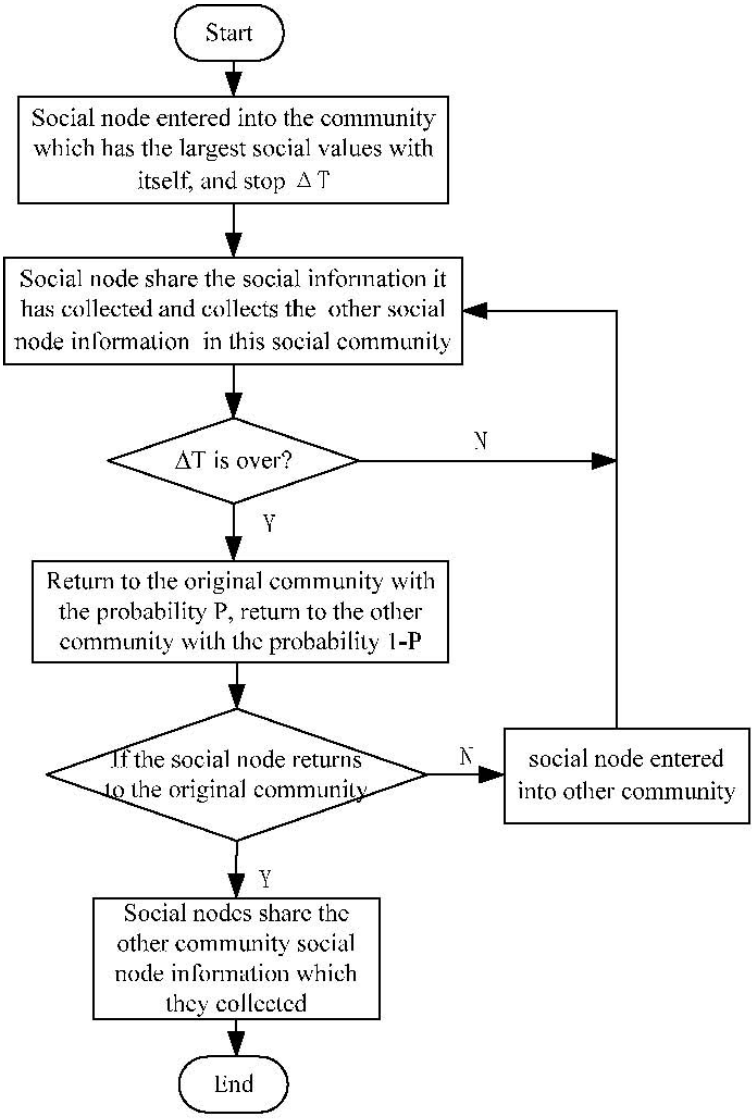

Fig. 5. Flow chart of message transfer mechanism among communities

4.3 The Message Transmission Mechanism between the Communities

The main idea of this mechanism that the community exploit the regression of the social node bring back social nodes information of different communities. Then calculate the social values according to the social nodes information. Finally chose the social node which has the largest social values for the destination community to transmit the message between the communities.

The operation of the mechanism is divided into the following 7 steps, the flow chart is shown in Fig. 5:

Step 1. Social node selects the the community has largest social values as a destination community, and then from the source community to the destination community.

Step 2. Social nodes stay in the destination community for a period of time ΔT , collecting social nodes information of destination community and acts as the node within the community transmit the message. At the same time the information collected from other communities by the social nodes distributed to the destination community nodes.

Step 3. After the ΔT , the social nodes return to the source community with probability of *P*, go to other communities with probability of *(1-P)* [18]. The calculation formula of the probability *P* is as follows:

$$p = \frac{\Delta T}{T_{back}} \tag{6}$$

T_{back} is simulation optimal value and set to *1/24* of the community division cycle.

Step 4. Social nodes return to the source community, transmit the information to the source community nodes which collected communities' social nodes.

Step 5. The node in the source community to obtain social node information, update social node information.

Step 6. Nodes in the community according to the social node routing information, select the social value of the largest social nodes of reach the destination community as the MCN, and transmitted the message to the destination community.

Step 7. After the message is transmitted to the destination community, transmission the message in the community according to the message transmission algorithm within community

4.4 The Message Storage Mechanism

When the node storage space is full, the obsolete was deleted the node according to the success rate that transmitted the message to the destination and the time of stored the message.

The operation of the mechanism is divided into the following 3 steps:

Step 1. The message was divided into two categories when the node storage space is full. The message reach to the destination node and has a social relationship with it was the first class message. If they have no social relationship was the second class message.

Step 2. The node checks if there are second class of messages in memory when it receives the message again. If there is, replace the longest time of storage messages in the second class of messages with that message. If no, eplace the longest time of storage messages in the first class of messages with that message.

Step 3. The node checks whether the message reaches to the destination node has a social relationship with it, if there is, it was the first class message. Otherwise, it was the second class message.

5 HECMTS Routing Algorithm

HECMTS routing algorithms are divided into three parts, which are routing algorithm within the community, routing algorithm between the communities and update of the information of social nodes.

5.1 Routing Algorithm within the Community

The message transmission within the community consists of the following 3 steps:

Step 1. The nodes carry the message move in the community when it encountered the other nodes judged whether this node is the destination node.

Step 2. The message is forwarded to the destination directly and removed from the cache if it is the destination.

Step 3. The two nodes exchange each others' SV (Summary Vector) if it is not the destination. The node containing the message will attach the node information to the SV table, and then according to the information of the SV distribute the message to the encountered node by the distribution of message distributing tasks mechanism transmit the message by the message transmission mechanism within the community. Meanwhile the two nodes update the node information records containing this message.

5.2 Routing Algorithm between the Communities

The message transmission between the communities consists of the following 4 steps:

Step 1. The node *m* in the source community S transfer messages to the node *n* in the destination community D. The node *m* inquire whether contains nodes belong to the D community in the S community. If there is, send the message to this node directly. Otherwise check the social node table whether contained the social nodes can reach to the D community.

Step 2. If the community S contains the social nodes can reach to the D community, the node m uses the message transmission mechanism within the community to transmit the message.

Step 3. If have not, the community S according to the social node table to find whether there is an indirect method to reach the D community. In other words, whether there are other communities that can be used as a forwarding community to connect the S community and the D community.

Step 4. If there are no forwarding communities, the source node carries a message until it encounters a node in the D community or the destination. While the social table updates the social nodes that satisfy the condition.

5.3 Update of the Information of Social Nodes

Step 1. Social nodes return to the source community from other communities and as a community node transmission message in the source community.

Step 2. The social nodes put other community social nodes information has changed part that they collected into the SV when they exchanged SV with other nodes.

Step 3. After the nodes within the community receive SV will extract the information of the community nodes and compare with their owe information, will save it if they are different. Otherwise not save. The social nodes will adding the changed information into the SV when it encountered other nodes and then send it out.

5.4 Performance Analysis of the HECMTS Algorithm

In order to demonstrate the correctness and effectiveness of the HECMTS algorithm, there are two lemmas.

Lemma 1: HECMTS algorithm in the community of message forwarding overhead is lower than the OSNCMTS.

Prove:

Assume that the network exists S、M_1、M_2、⋯、M_{n1}、D_1、⋯、D_{n2} that has n_1+n_2+1 communities. S community to the Di community have ni social nodes, mi is the maximum social values of the social node number with the D_i community. S has not social nodes to reach the D_j community but has number of n_T social nodes to reach to the number of k ($\{k|1 \leqslant k \leqslant n_2\}$) communities M_k. The number of social nodes have n_{Tj} that from M_k community to D_j community. m_{Tj} was the number of number of that has the largest social values with the D_j community. The overhead that the community node i transmits the message from one community to another is E_i.

From the OSNCMTS algorithm, the overhead that the S community nodes transmit the message to the D_i community is $E_{OSNCMTSi}$.

$$E_{OSNCMTS\mathrm{i}} = \sum_{w=1}^{n} E_w \tag{7}$$

The overhead that the S community transmits the message to the D_j community is $E_{OSNCMTSj}$

$$E_{OSNCMTSj} = \sum_{T=1}^{\mathrm{k}} \sum_{l=1}^{n_T} E_l + \sum_{T=1}^{\mathrm{k}} \sum_{q=1}^{n_{Tj}} E_q = \sum_{\mathrm{T}=1}^{k} (\sum_{l=1}^{n_T} E_l + \sum_{q=1}^{n_{Tj}} E_q) \tag{8}$$

From the HECMTS algorithm, the overhead that the S community transmits the message to the D_1 community is $E`_{HECMTSi}$.

$$E'_{HECMTSi} = \sum_{w=1}^{n} E_w \tag{9}$$

The overhead that the S community transmits the message to the D_j community is $E`_{HECMTSj}$

$$E'_{HECMTSj} = \sum_{T=1}^{k} \sum_{l=1}^{m_T} E_l + \sum_{T=1}^{k} \sum_{q=1}^{m_{Tj}} E_q = \sum_{T=1}^{k} (\sum_{l=1}^{m_T} E_l + \sum_{q=1}^{m_{Tj}} E_q) \tag{10}$$

Because of $m_T < n_T$, $m_{Tj} < n_{Tj}$, therefore:

$$E'_{HECMTSi} + E'_{HECMTSj} < E_{OSNCMTS\mathrm{i}} + E_{OSNCMTSj} \tag{11}$$

Lemma 2: The success rate of the HECMTS algorithm is higher than OSNCMTS algorithm in the community.

Prove:

Assume that there are N_S、N_2、⋯、N_k、⋯、N_D in the community, N_S transmits the message to the N_D, N_i arrived at N_j with probability P_{ij}. There are m nodes can be transmitted the message to the N_D.

From the OSNCMTS algorithm, the probability of the node N_i to the node N_D within the community was divided into direct transmission probability P_{DT_i} and indirect transmission probability P_{IT_i} and

$$P_{DT_i} = P_{iD} \tag{12}$$

$$P_{IT_i} = \prod_{j!=i}^{m} P_{ij} P_{jD} \tag{13}$$

P'_{SD} was the probability that the source N_S to the destination N_D.

$$P'_{SD} = \sum_{i=1}^{L} P_i (P_{DT_i} + P_{IT_i}) \tag{14}$$

From the HECMTS algorithm, P_{SD} was the probability that the source N_S to the destination N_D.

$$P_{SD} = \sum_{i=1}^{L} P_i (P_{DT_i} + P_{IT_i}) \tag{15}$$

Because the HECMTS algorithm uses the community association matrix and node probability within the community to distribute message, it avoids that the message is squeezed in a higher probability node. So

$$L' < L \tag{16}$$

$$P_{SD} = P'_{SD} + \sum_{i=L+1}^{L-L'} P_i \left(P_{DT_i} + P_{IT_i} \right) \tag{17}$$

Because of $L' < L$, so

$$P_{SD} - P'_{SD} > 0 \tag{18}$$

$$P_{SD} > P'_{SD} \tag{19}$$

5.5 Complexity Analysis of HECMTS Algorithm

Because the HECMTS algorithm uses a multi copy transmission message, it is difficult to do complex derivation. The paper makes the following assumptions: There have *m* communities and each community have *N* nodes in the entire network. In the community, the probability of node N_S and node N_D encounter is less than that of other nodes and N_D nodes and the probability of other nodes encountered each other were *P*. The average node encounter time is *t*, the time of the nodes carry the message from one community to another community is t_c. In this paper, the complexity of HECMTS algorithm is derived from 3 aspects: time, storage and communication.

1. Time complexity

The time complexity of the HECMTS algorithm is divided into the time complexity within the community C_i and the time complexity between the communities C_o.

$$
\begin{aligned}
C_{\mathrm{i}} &= O(\sum_{i=1}^{n-1} itP(1-P)^{i-1}) \\
&= O(tp\sum_{i=1}^{n-1} i(1-p)^{i-1}) \\
&= O(t(\frac{1-np(1-p)^{n-1}-(1-p)^{n}}{p}))
\end{aligned}
\tag{20}
$$

In the computation of C_o, the message transmission is proportional to the number of the community that the message has through. So

$$C_0 = O((m-1)t_c) \tag{21}$$

2. Storage complexity

The nodes stored data message had positive correlation with M, T, N after the network running the time t. In the extreme case that the stored message is always not found the destination node, so the storage complexity C_s is

$$C_0 = O(MTN) \tag{22}$$

3. Communication complexity

Because of a data message need N-1 hops to forward it to the destination node in the most extreme cases, so the communication complexity C_t is

$$C_t = O(N) \tag{23}$$

6 Simulation Experiments and Results

In this paper, we use ONE1.3.0 simulation platform to simulate the performance of the algorithm and compared with the typical algorithms of opportunistic network of SW and Prophet and OSNCTMS.

6.1 Simulation Statistics

In order to verify the effectiveness of the HECMTS algorithm, this paper compares the Prophet, SW and OSNCMTS algorithms from the routing overhead rate, average end-to-end delay and message delivery success rate.

(1) Routing overhead rate: The ratio of the total number of messages failed to reach the destination node and the total number of messages success to reach the destination node in the network simulation time. And the calculation formula:

$$R_{\mathrm{ait}} = \frac{\sum_{i=1}^{n} S_i - T_s}{T_s} \tag{24}$$

Where the R_{ait} is routing overhead rate, T_s is the total number of messages success to reach the destination node. $\sum_{i=1}^{n} S_i$ is the total number of messages generated by all the source node.

(2) Average end-to-end delay: Average delay of all messages to the destination node. The calculation formula:

$$\bar{T} = \frac{\sum_{i=1} T_i}{D} \tag{25}$$

Where the T_i is delay of the i-th message reach to the destination. D is the total numbers of messages have reached the destination.

(3) Message delivery success rate: The number of messages successfully reached the destination

accounts for the proportion of the total number of the messages source node has send in the network. The calculation formula:

$$D_{rate} = \frac{D}{S} \tag{26}$$

Where the D The number of messages successfully reached the destination, S is the total number of the messages source node has send.

6.2 Simulation Settings

The simulation scene parameter settings are shown in Table 1.

Table 1. Simulation parameter

Parameter item (unit)	Configuration data
Network coverage area (M^2)	4500×3400
Network simulation time (h)	24
Number of pedestrian nodes	100
Number of tram nodes	10
Number of buses	20
Pedestrian node moving speed (m/s)	[0.6,1.4]
Tram node moving speed (m/s)	[8.7,13.9]
Vehicle node moving speed (m/s)	[7.4,9.7]
Message interval time (s)	[25,35]
Node cache (Mbit)	[5,25]
P_{th}	0.5
Community division cycle	4h

6.3 Analysis of Simulation Results

Routing overhead rate. Fig. 6 is the result of the effect of the node cache size on the routing overhead ratio of different algorithms. From the figure we know that the routing overhead rate of the 4 algorithms decreases gradually with the increase of buffer space. This is mainly due to the increase in the buffer space, increasing the success rate of the message transmission. From the figure, we also know that the HECMTS algorithm is better than the other 3 algorithms. The main reason is that the HECMTS algorithm according to community matrix assigns the message and distribute task within the community. Avoid large number of messages overstock on high probability nodes increases the success rate of message transmission; between the communities, reduce the transmission of messages in the middle of the community through the direct or indirect choice of social nodes.

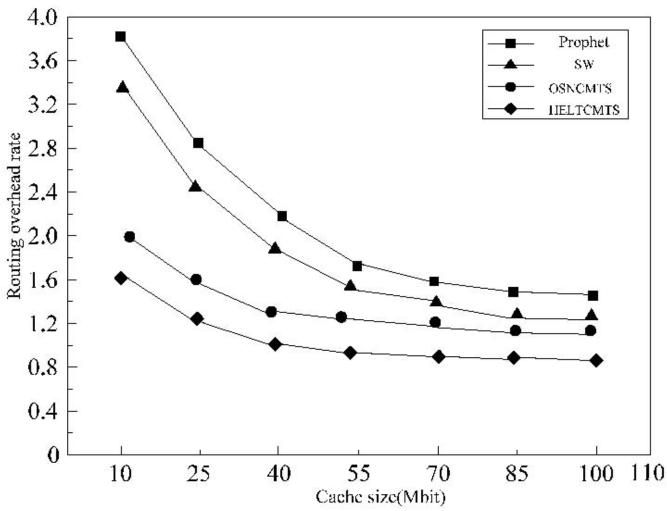

Fig. 6. Routing overhead rate

Average delay. Fig. 7 is the result of the effect of the node cache size on the average end-to-end delay of different algorithms. By the graph, when the node buffer space increases, the delay increases. Because the Prophet algorithm uses a single copy of the transmission message, the message in the network is distributed slowly, so its average delay is the maximum. HECMTS algorithm is better than the other 3 algorithms, this because of priority transmission message that FN have a large probability to transmit it to the destination when transmit the message within the community through the HECMTS algorithm. Reducing the delay and number of hops when transmit transmit the message. Between the communities, by selecting large social values of social nodes or have the purpose of selecting intermediate community transfer messages which can reduce the number of community that the message has passed and shorten the time of the message reaches the destination community.

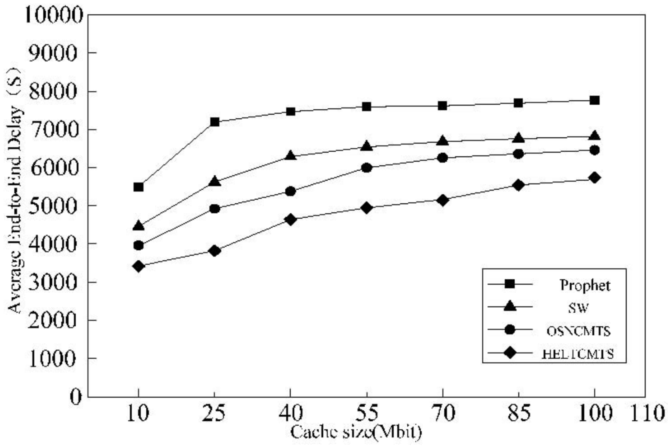

Fig.7. Delay comparison

Success rate. Fig. 8 is the simulation results of the effect of the node buffer size on the success rate of different algorithms. By graph, when the node cache is increasing, the success rate of the four algorithms is improved. This is because of with the increase of the node cache, the time of the message stored in storage space was large and the probability of the message arrival destination increases. HECMTS algorithm is better than the other 3 algorithms, mainly because of the HECMTS algorithm to transmit messages within the community the message along the larger probability node to transmit, which avoid the distribution tasks overstock on one node and increased the success rate of message transmission. Meanwhile delete messages that have no social relationship with the destination, reduce the storage of unnecessary messages. Between the communities, by grasping the entire network of social node information, have the purpose of selecting social nodes to transmit messages, avoiding the blind forwarding to make the message backlog in the forwarding community.

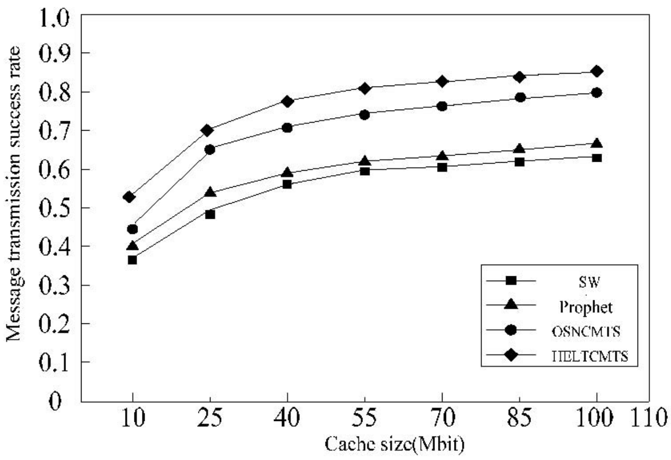

Fig. 8. Comparison of message transmission success rate

7 Conclusion

In this paper, we propose a new algorithm for network routing based on community according to the characteristic of the mobile nodes have sociality. The algorithm is improved on the basis of OSNCTMS algorithm, the nodes are divided into different communities by the social nature of the node movement. Within the community based on community matrix, using the improved algorithm Spray and Wait timely dissemination of message and make it transmitted along the larger of the probability; Between the communities, by selecting the appropriate social node, make the message reaches the destination as soon as possible. By collecting the information of the social nodes as the basis for selecting the active node between the communities, how to update information of active node timely and effective is the focus of this future consideration.

References

[1] J. Peng, M.S. Li, T. Liu, Nodal sociality-based data forwarding for opportunistic networks, Journal of Sichuan University (engineering science edition) 45(5)(2013) 57-63.

[2] Z. Ren, R. Huang, Q.B. Chen, Routing protocols for opportunistic networks, Journal of Computer Application 30(3)(2010) 723-727.

[3] W. Gao, G. Cao, T.L. Porta, On exploiting transient social contact patterns for data forwarding in delay-tolerant networks, IEEE Transactions on Mobile Computing 12(1)(2013) 193-202.

[4] K. Sugiyama, T. Kubo, A. Tagami, T. Hasegawa, Mean free path applied to message dissemination in opportunistic networks, in: Proc. Computer Communications Workshops, 2015.

[5] J.W. Niu, X. Zhou, Y. Liu, A message transmission scheme for community-based opportunistic network, Journal of Computer Research and Development 46(12)(2009) 2068-2075.

[6] A. Vahdat, D. Becker, Epidemic Routing for Partially Connected Ad Hoc Networks, Duke University, Durham, 2000.

[7] A. Lindgren, A. Doria, O. Schelen, Probabilistic routing in intermittently connected networks, Acm Sigmobile Mobile Computing & Communications Review 7(3)(2003) 239-254.

[8] T. Spyropoulos, K. Psounis, C.S. Raghavendra, Spray and wait: an efficient routing scheme for intermittently connected mobile networks, in Proc. the 2005 ACM SIGCOMM Workshop on Delay-tolerant Networking, 2015.

[9] M. Musolesi, S. Hailes, C. Mascolo, Adaptive routing for intermitlently connected mobile ad hoc networks, in Proc. the 6th International Symposium on Wireless, Mobile and Multimedia Networks, 2005.

[10] S.K. Dhurandher, S. Borah, I. Woungang, D.K. Sharma, K. Arora, D. Agarwal, EDR: an encounter and distance based routing protocol for opportunistic networks, in: Proc. the IEEE International Conference on Advanced Information NETWORKING and Applications, 2016.

[11] S.K. Dhurandher, D.K. Sharma, I. Woungang, Mobility models-based performance evaluation of the history based prediction for routing protocol for infrastructure-less opportunistic networks, in: Proc. 10th IEEE MOBIQUITOUS, 2013.

[12] B.J. Qiao, T.Z Li, Community construction algorithm based on radiation propagation in opportunistic network, Journal of Henan University Natural Science 46(5)(2016) 562-567.

[13] D.R. Pan, M. Lin, L.J. Chen, J.P. Sun, Multiple-copy opportunistic network routing based on transitivity, Journal of Nanjing University of Science and Technology 36(4)(2012) 573-578.

[14] P. Hui, J. Crowcroft, How small labels create big improvements, in: Proc. the 5th Annual IEEE International Conference on Computing and Communications Workshops, 2007.

[15] P. Hui, J. Crowcroft, Y. Eiko, Bubble rap: social-based forwarding in delay-tolerant networks, IEEE Transactions on Mobile Computing 10(11)(2011) 1576-1589.

[16] Y.H. Liu, Y. Gao, J.L. Qiao, C.H. Tan, Community-based message transmission scheme in opportunistic social networks, Journal of Computer Application 33(5)(2013) 1212-1216.

[17] J. Duch, A. Arenas, Community detection in complex networks using extremal optimization, Physical Review E-Statistical, Nonlinear, and Soft Matter Physics 72(2)(2005) 102-104.

[18] H. Ma, Q.W. Du, Research on opportunistic network routing based on community structure, Electronic Science and technology 26(5)(2013) 117-121.