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Messsage Spreading Estimating Methods in Ubiquitous Networks

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***Abstract*—According to the storing-carrying-forwarding method in the ubiquitous network, the status on the packet transmitting has the relationship with the spreading degree of messages, and the distributed estimating results can make the assistance on the designing on the routing and cache management mechanism. A novel method to estimate spreading degree of message is proposed in our paper. First, we estimate the copies number of each message according to delivery mechanism in ubiquitous networks, and then the copies number of each message are mapped into spreading degree of messages using non-uniform quantization methods. Simulations show the proposed estimating method is accurate, and the scalability can be guaranteed.**

Keywords-ubiquitous networks; spreading degree; delivery mechansim; non-uniform quantization

I. INTRODUCTION

Routing protocol of mobile ad hoc network (MANET) [1] requires at least one path existing from source to destination nodes before any message can be sent. However, in many realistic environments, communications between nodes cannot be implemented effectively due to nodal mobility, 1ow density etc. Ubiquitous networks [2,3] utilize the meeting opportunities brought by node movement, and implement communications between nodes based on the "store-carry-forward" routing mechanism. As can be seen, a node may store a message in its buffer and carry it along for a long period of time, until it meets the message's destination nodes or proper relay nodes. Additionally, multiple message replicas are often propagated to increase message delivery probability in ubiquitous networks. Obviously, if we make use of message's spreading degree to design routing and cache management protocols, network performance will be improved effectively.

Recently, some routing protocols and cache management methods have been proposed based on mobile node's behavior and message's information. In [4], the authors estimate the relationship between messages and nodes, and propose a new cache management mechanism using the relationship. In [5], the authors exploit the context of mobile nodes (speed, direction of movement and radio range) to estimate the size of a contact window for better forwarding decisions, and allocate utility for each message. Messages are first replicated according to the order of highest utility, and removed from the buffers in the reverse order. In [6], the authors assign an "importance weight" to each message. The message with smaller "importance weight" will be deleted firstly when queue is full. In [7], the node's position and moving direction are utilized to make the decision of message forwarding. The principle is that the message will be forwarded when its position is closer to the message's destination and the node is moving to the message's destination. In [8], the authors take both the energy and speed to calculate the weight of node, and messages are forwarded according to the estimating results. However, spreading degree of message hasn't been considered in the above researches.

This paper proposes an effective method to estimate spreading degree of messages. We first estimate the copies number of each message according to delivery mechanism in ubiquitous networks, and then copies number of each message are mapped into spreading degree of messages using non-uniform quantization methods. The method is useful to design more effective routing and cache management protocols.

The rest of the paper is organized as follows. We first present the method to estimate spreading degree of message in Section II. In section III we give simulation results that confirm the validity of the proposed method. Lastly, some conclusions and ideas for future work are obtained.

II. SPREADING DEGREE OF MESSAGE ESTIMATE

In this section, we will first introduce the architecture of ubiquitous network and storing-carrying-forwarding method, and then show the principles of the number of message copies predicting. Finally, we propose the method to estimate spreading degree of messages according to number of message copies.

A. The Architecture of Ubiquitous Network and Storing-Carrying-Forwarding Method

The architecture of ubiquitous network is slightly different from that of traditional network. it is inserted a new protocol layer between the application layer and the transport layer of nodes to implement storing-carrying-forwarding mechanism for information exchange. This layer is called bundle layer[2]. The architecture of ubiquitous network is shown in Fig.1. Bundle layer mainly achieves storing-carrying-forwarding functions in ubiquitous network, and also implements routing functions. Bundle layer sends and receives messages without transferring them while the node as a host. Bundle layer stores, carries and forwards messages among nodes in the same region while the node as a router. Bundle layer has storage capacity and implements security

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checks to ensure message forwarded while the node as a gateway. Simultaneously, bundle layer transfers messages among different regions.

In ubiquitous network, routing protocols take storing-carrying-forwarding method. As is shown in Fig.1. After node receives messages, usually, it doesn't immediately forward these messages but stores them in its own buffer and carries them along for a period of time. if the node encounters any other node when wandering, it forwards these messages out. The method can overcome the network divisions and the difficulties that end-to-end paths don't exist, and deliver messages to destination node relying on constantly moving.

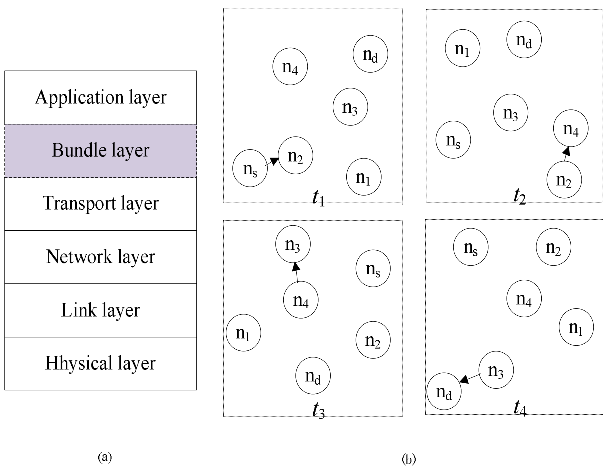

Figure 1. (a)The architecture of ubiquitous network, (b) The storing-carrying-forwarding method.

B. Number of Message Copies

In ubiquitous networks, multiple message replicas are often used to improve message delivery rate and reduce message transmission delay. When the message needs to be sent by node, it is firstly assigned a unique identity (*ID*) and stored in this node's buffer. And then the message waits for communication opportunities. Two nodes will exchange summary vector (*SV*) when they meet, and request those messages which don't exist in their own buffers but in the other's buffer. When the operation complete, two nodes have the same messages in their buffers. With the above process executed continuously, the message can be delivered to its destination node successfully or its Time To Live (*TTL*) expires. Thus, according to delivery mechanism in ubiquitous networks, propagation process of multiple messages in networks is shown in Fig.2.

As Fig.2 shows, propagation process of message can be described by the structure of tree, which is called propagation tree. We can estimate the copies number of message by propagation tree. Firstly, the parameter of propagation depth is defined:

Definition I. Propagation Depth is the level in propagation tree, represented by *H*. *H* of each message is set as 1 when they are created by the node in network, and when message is forwarded successfully, its Propagation Depth (*H*) plus 1 accordingly.

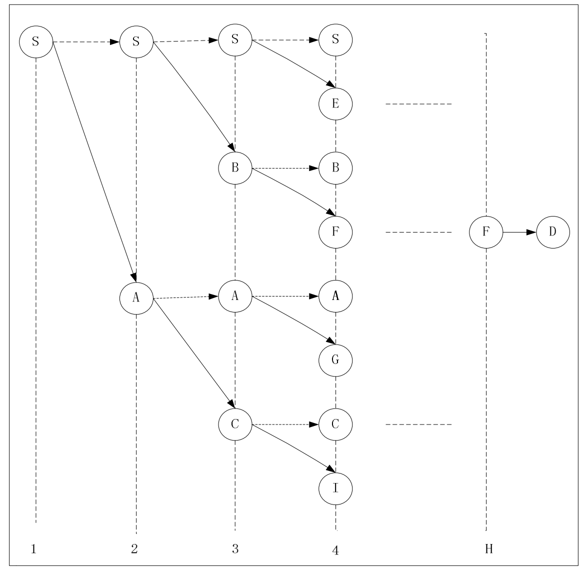

Figure 2. Propagation process of multiple messages.

From Fig.2 we can see that the copies number of message will be multiplied one time when its *H* adds one. It is thus clear that when Propagation Depth of messages increases, their copies number will increase by exponential function with the parameter of two. Thus, we can draw a conclusion that when Propagation Depth of messages is *H*, its copies number can be expressed by (1).

$$NC = 2^{H-1}. \tag{1}$$

For the purpose of improving network performance, we may consider other factors, such as node activity degree, node energy etc. However, the range of various factors may be greatly different. So we need to restrict them within a certain interval. Choosing what quantization method is the key to convert interval, especially when the converting range is large. The conversion from large interval to small interval may concentrate data distribution and make distinction degree of data smaller. So we need to use a proper quantization method in order to make the distribution smooth. This paper defines the number of message copies to the interval [0, 1] using non-uniform quantization method [9] by *A*-Law Coding method, which can ensure that data is smoothly distributed in interval.

C. Spreading Degree of Messages

The smallest value of message (*M*)'s copies number is zero, and the biggest value is the number of nodes in network, which means that all nodes have a copy of *M*. At time *t*, number of *M* copies is marked by $NC_M(t)$, and it is a certain integer value in interval [0, *N*]. Let $P_M(t)$ denote spreading degree of message, which express the mapping value of $NC_M(t)$ within the interval [0, 1]. As can be seen, the value of $P_M(t)$ is larger while the copies of M in network increase.

The non-uniform quantization method in A-Law Coding divide the interval [0, 1] into eight segments, and these dividing points are 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2. Let d_j denotes these dividing points. Each segment is divided into sixteen smaller segment evenly again, and the smallest quantization interval is 1/2048. The correspondences of various parameters are shown in TABLE I.

TABLE I. THE CORRESPONDENCES OF VARIOUS PARAMETER IN NONUNIFORM QUANTIZATION

segment	1	2	3	4	5	6	7	8
boundary of segments	0 ~ 16	16 ~ 32	32 ~ 64	64 ~ 128	128 ~ 256	256 ~ 512	512 ~ 1024	1024 ~ 2048
starting value	0	16	32	64	128	256	512	1024
quantization interval	1	1	2	4	8	16	32	64

With the non-uniform quantization method, the quantization error can be reduced effectively. Additionally, according to the map from $NC_M(t)$ to $P_M(t)$, the largest value of $NC_M(t)$ is N, so the smallest quantization interval is N/2048. The procedure of non-uniform quantization method is shown as follow:

Step 1. we map $NC_M(t)$ into a integer $L_M(t)$ within the interval [0, 2048] by (2).

$$L_M(t) = [NC_M(t) \times 2048 / N]. \quad (2)$$

Step 2. According to TABLE I, we determine the attributive interval of $L_M(t)$. e.g. if $L_M(t)$ equals 48, it is is situated within the third segment .

Step 3. On the basis of characteristic of uniform quantization in segment, we establish a map from $NC_M(t)$ to $P_M(t)$ by (3). If $L_M(t)$ is situated within j segment, the spreading degree of message is :

$$P_M(t) = d_j + \{(L_M(t) - D_j)/\Delta_j\} \times \{(d_{j+1} - d_j)/16\}. \quad (3)$$

D_j is the starting value of j segment, and $_j$ is the quantization interval of j segment in TABLE I. As what can be seen, the spreading degree of message evaluated by (3) will change gradually with number of message copies dynamically, which can help us improve performance of network effectively when designing routing and cache management protocol in ubiquitous networks.

III. SIMULATION RESULT AND PERFORMANCE ANALYSISI

A. Simulation Environment and Parameter Settings

In this section, we will verify the accuracy of the estimation on number of message copies by using the simulator Opportunistic Network Environment (*ONE*)[10]. And then we compare the effect of non-uniform quantization and uniform quantization on data distribution by the simulating results. The parameter settings in the simulation environment are listed in TABLE II.

TABLE II. PARAMETER SETTINGS

Parameter Name	Parameter Value
Simulation time (s)	9600
Movement model	Random Waypoint
Router	Epidemic
World size (m)	800 × 800
Transmission range (m)	10
Transmit speed (kBps)	250
Message size (kB)	200-300
Number of nodes	70
Nodal speed (m/s)	0.5-1.5
Buffer size (M)	5
Time To Live (min)	50

B. Accuracy of Estimation on Number of Message Copies

The accuracy of estimation on spreading degree of message is determined by the accuracy of estimation on the number of message copies. In this subsection, three scenarios is established, the simulated data are gathered for different phase during the simulation, beginning, middle and the end respectively. Further, the average number of message copies in the three periods is computed. Finally, we compare the simulating statistic value with the theoretical estimating value. The results are shown in Fig.3. At the beginning of message propagation (when H is one and two) , there is tiny error between the simulating statistic value and the theoretical estimating value. However, When H continued to increase, the error also arises. Due to the difference of nodal speeds, the propagation speed of different copies is little different. As a result, the error between the simulating value and the estimating value, but the difference is less than 7.1%.

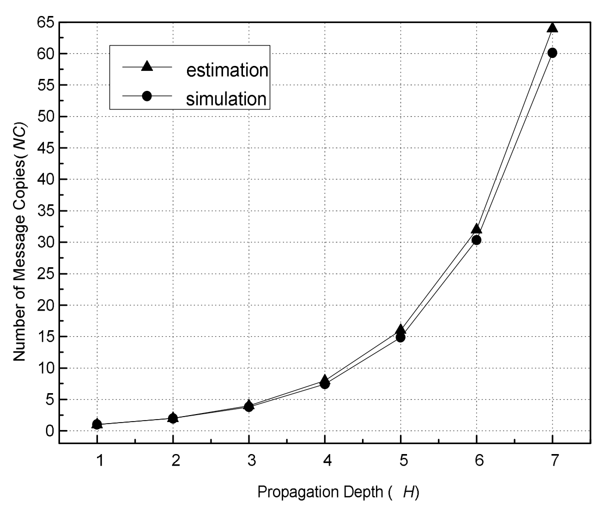

Figure 3. The comparison between the simulating value and the estimating value.

C. *Effect of Non-uniform Quantization Method on Distribution of Spreading Degree*

This test gathers statistics the number of messages in each interval of spreading degree at time 4000s under non-uniform quantization method, and is compared with the result under uniform quantization method. Fig.4 shows spreading degree value of messages got by uniform quantization method mainly distribute in the first half of the whole interval when the simulating time is 4000s. With the number of message copies increasing the probability that messages have been successfully delivered to destination will become higher. In networks, copies of messages which have been delivered successfully will be deleted gradually, and only these messages which can not be delivered successfully have more copies. So the values of messages spreading degree estimated by uniform quantization method distribute mainly in the first half of whole interval. But after non-uniform quantization begins, spreading degree values of messages distribute smoothly in whole interval so that nodes can effectively measure the difference on spreading degree of different messages in the networks.

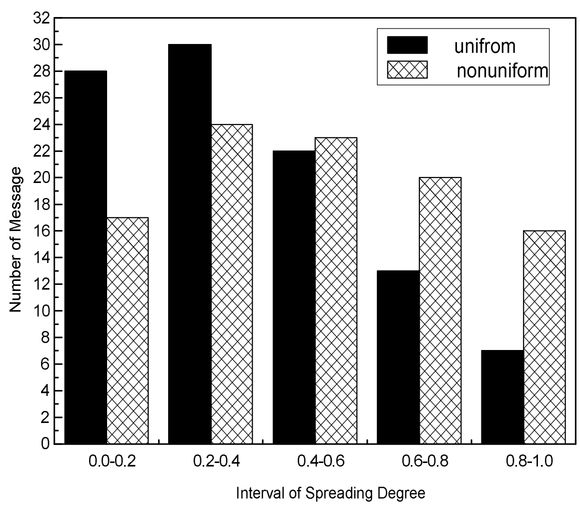

Figure 4. The comparison between non-uniform quantization and unifrom quantization.

IV. CONCLUSION

Evaluating the spreading degree of message will help us to design effective routing and cache management protocol. This paper proposes a method to estimate spreading degree of message. The simulation results show that proposed method can reflect spreading degree of message accurately. Our future work is to design reasonable and effective routing protocol by taking advantage of spreading degree of message or combining other factors.

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