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A DTN ROUTING BASED ON A ADAPTIVE DYNAMIC AGING FACTOR IN URBAN ENVIRONMENTS

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Abstract

Delay Tolerant Network(DTN) is an important part of future smart city development. There are corresponding routing algorithms for different scenarios. In urban environments, the Prophet is a more reliable routing method than others for DNT due to changing rules of periodic life. However, the delivery predictability is calculated by an aging constant γ in the Prophet algorithm, then probabilities aging rate of less-active nodes are also the same with active nodes. Therefore, the Prophet will result in inconspicuous probabilities of nodes. Finally, the whole network is not efficient due to the Prophet. To fight with challenge we have proposed an Adaptive Dynamic Aging Factor (ADAF) method. ADAF routing algorithm can effectively improve the performance of the entire DNT in urban scenarios, so that each node can effectively distinguish active degree of nodes. Results of simulation verified the performance of proposed ADAF under an urban scenario, and the results suggest that the ADAF outperforms the Prophet routing algorithm in delivery ratio and network overhead ratio.

Keywords： Delay Tolerant Network (DTN), smart city, delivery predictability, Overhead ratio, successful delivery ratio, Adaptive Dynamic Aging Factor

Introduction

Delay Tolerant Network(DTN), with sevral kinds of nodes, requires an efficient routing protocol in urban environments. DTN is relatively new type of network structure [1]. Special features of DTN include high latency, long disconnection periods and constantly network topology[2]. Beyond that, the biggest difference between the DNT and other networks is that there are no definite paths between source nodes and destination nodes. The transmission of information depends on the method of store-carry-forward. Because DNT has the characteristics above. DNT is extensively used in other scenarios such as military network, wild research, vehicle network, interplanetary network and so on. In addition, urban environments are the most important scenarios of the DNT. Since cities are the main places for data generating and consuming, and with the development of smart city, the use of DTN has attracted more and more academic attention.

Along with the popularization of mobile smart devices such as mobile phones, smart bracelets, vehicle-mounted systems, there are a large amount of equipments to be the carrier of information transmission in urban environments[3]. The activity of each node is inseparable from people's behaviors. Almost everyone's daily life is regular, such as going to work in the morning, spending their day at work, and commuting back to their homes at evenings. In this way, everyone can meet certain people or cars periodically. According to the above rules, Franks Ekman proposed the working day model in 2008[4]. The model intuitively depicts the movement pattern of people, the statistical features of the model is similar to real-world traces.

In urban environments, the Prophet is a more reliable routing method than others for DNT due to changing rules of periodic life. In the Prophet routing algorithm, when two nodes are not encountered for a long time, the opportunity they encounter will drop exponentially with time[5]. However, the base of the exponent is a given an aging constant. Then, the activity level of each node is exactly the same. However, as a result of the existence of active and slow nodes in social networks, if an aging constant is given as Prophet routing algorithm, so that the performance of the entire networks decrease dramatically over time and nodes. Moreover, the loss ratio of messages will sharp increase with the number of nodes growing. Therefore, if a routing algorithm can adaptively adjust the aging factor. Then, active nodes have large aging factors, and slow nodes have small aging factors. So the overhead ratio and the successful delivery ratio will be greatly improved. In this paper, an adaptive dynamic aging factor is proposed to solve the above problems.

This paper has two main contributions; Firstly, an adaptive dynamic aging factor (ADAF) algorithm is proposed to improve the performance of the entire network. Secondly, when a pair of nodes meets with similar delivery predictability values, the condition of the sending or not of the message is changed, and the distance priority is used.

The rest of the paper is organized as follows: In Sect. 3, we will describe our proposed method with more details. Section 4 will present the ADAF simulation results that show a better packet delivery ratio and overhead ratio than Prophet algorithm in urban scenarios. Finally, we will present conclusion in Sect. 5.

Related Works

With the rapid development of our societies, cities have become the focus of DTN research. Because cities are the main places for data generation and consumption, it also brings great opportunities and challenges to DTN. Along with the popularization of mobile intelligent terminals and the continuous development of machine learning, DNT will be made full use in meteorological data acquisition, data processing data acquisition, data mining and other fields[6].

DNT development is an important component of urban development and an effective way to build smart cities in the future[7]. However, the deployment of DNT in urban environments differs greatly from those of other environments, because the urban environments have a lot of unique characteristics. For example, The urban environment presents the everyday life of average people that go to work in the morning, spend their day at work, and commute back to their homes at evenings[8]. In addition, everyone will regularly encounter certain people and take some transportations. There are lots of unique features of cities like this. Therefore, the appropriate WDM model will have a higher degree of simulation with the urban environment. The model of WDM is shown in Figure 1.

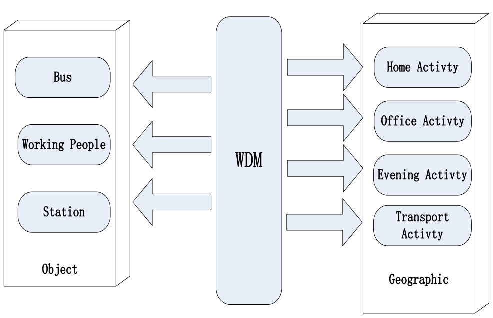

Figure 1. Simulation scenario moving model architecture

Anders Lindgren proposed the Prophet algorithm for regular activities in urban environments. However, the entire network performance is not very good due to an aging constant in the Prophety algorithm. Therefore, this paper presents an adaptive dynamic aging factor, which effectively improves the performance of the whole network.

ADAF Routing Algorithm

The ADAF algorithm contains two parts: (1) the adaptive dynamic aging factor, (2) the distance priority criteria. In urban environments, the prior probability of any node changes exponentially with time. The bottom of the exponent should be associated with the activity of each node in cities, rather than specifying an aging constant for each node. In addition, when probabilities of the same message being delivered from two paths are very similar, we only compare values of two probabilities that the results might not be very good. In ADAF algorithm, we regard two very similar probabilities as two equal probabilities, then distances of two nodes to the destination are determinants of decision about the message being sent or not. Here are two parts to illustrate this algorithm in details[9].

If a pair of nodes does not encounter each other in a while, they are less likely to be good forwarders of messages to each other, thus the delivery predictability values must age, being reduced in the process. The delivery predictability values of aging are calculated by Eq.(1).

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$$P(a,b) = P(a,b)_{old} * \gamma^{k} \quad (1)$$

γ is the aging constant, k is the number of time units that have elapsed since the last time the metric was aged, and the literature has proved that the best value of **Error! Reference source not found.** γ is 0.98.

The adaptive dynamic aging factor

In ADAF, adaptive dynamic aging factor has two functions, one is to make the aging rate of the delivery ratio positively correlated with the activity of nodes, the other is the introduction of the adaptive aging factor to make the entire network route more rational.

Let's suppose that the number of nodes is N in the entire network. We can obtain the number and times of encounters between each node and other nodes in the simulation process. Then, we can define the activity of any node by using the number and times of encounters with other nodes. Therefore, we can use the activity of each node to define the respective aging factors. Thus, each node has the same aging factor as its own active degree.

The number and times of encounters between each node and the other nodes are expressed as Eq.(2) and Eq.(3):

$$N(t) = \begin{bmatrix} N_{(0,1)}(t) & \ldots & N_{(0,n-1)}(t) \\ \ldots & \ldots & \ldots \\ N_{(n-1,0)}(t) & \ldots & N_{(n-1,n-2)}(t) \end{bmatrix} \quad (2)$$

$$T(t) = \begin{bmatrix} T_{(0,1)}(t) & \ldots & T_{(0,n-1)}(t) \\ \ldots & \ldots & \ldots \\ T_{(n-1,0)}(t) & \ldots & T_{(n-1,n-2)}(t) \end{bmatrix} \quad (3)$$

Where the $N(t)$ and $T(t)$ indicate the number of encounters and the times of encounters when time is t, **Error! Reference source not found.**and **Error! Reference source not found.** indicate the number of encounters and the times of encounters between node i and node j when time is t.

When the time is t, the number and times of encounters of the node i are expressed as Eq.(4) and Eq.(5):

$$N_{(\mathrm{i},total)}(\tau)=\sum_{j=0}^{n}\sum_{t=0}^{\tau}N_{(\mathrm{i},j)}(t) \tag{4}$$

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$$T_{(i,total)}(\tau)=\sum_{j=0}^{n}\sum_{t=0}^{\tau}T_{(\mathrm{i},j)}(t) \tag{5}$$

Where **Error! Reference source not found.** $N_{(\mathrm{i},total)}(\tau)$ and $T_{(i,total)}(\tau)$ **Error! Reference source not found.** indicate the total number of encounters and the times of encounters where time is **Error! Reference source not found.**.

We can calculate the adaptive dynamic aging factor of each node by using the following formula Eq.(6), after the number and times of encounters of each node and other nodes.

$$\gamma_{\mathrm{i}}(\tau)=\varepsilon_1\frac{N_{(\mathrm{i},total)}(\tau)}{N_{(\mathrm{i},total)}(\tau)+N_{(\mathrm{j},total)}(\tau)}+\varepsilon_2\frac{T_{(\mathrm{i},total)}(\tau)}{T_{(\mathrm{i},total)}(\tau)+T_{(\mathrm{j},total)}(\tau)}+\sigma$$ **Error! Reference source not found.** (6)

When node i and node j are going to establish a connection, where **Error! Reference source not found.** indicates the aging factor value of node i when the time is **Error! Reference source not found.**. **Error! Reference source not found.** and **Error! Reference source not found.** are proportional weights, and the optimal solution with lots of experiments is: $\varepsilon_1=0.9$, $\varepsilon_2=0.1$. **Error! Reference source not found.** indicates a weight value, and the best value of **Error! Reference source not found.** is 0.3. Two particular situations occur as Eq.(7):

$$\begin{cases}\gamma_{\mathrm{i}}(\tau)=0.98, if \quad N_{(\mathrm{i},total)}(\tau)+N_{(\mathrm{j},total)}(\tau)=0\\ \gamma_{\mathrm{i}}(\tau)=0.98 \qquad\qquad if\ \gamma_{\mathrm{i}}(\tau)>1\end{cases} \tag{7}$$

At the beginning of a new day, the number and the times of one person encounters others are empty. According to this reality, a decision condition is required: if a pair of nodes that need to establish a connection have numbers that add up to 0, then the initial aging factor is set to 0.98. In addition, if the **Error! Reference source not found.** is bigger than 1, the node is very active, and the aging factor of this node is set directly to 0.98.

The distance priority criteria

In ADAF, when a pair of nodes connected, its delivery predictabilities about a piece of message to destination are very closed. And, if the difference between the two probabilities are 0.03, we determine probabilities that the pair nodes arrive at the destination being equal. Then distances which they arrive at the destination are key . Short distance of one node serve as a vehicle for sending this message. The distance is calculated by Eq.(8).

$$S_{distance}=\sqrt{(X-X_{des})^2+(Y-Y_{des})^2} \tag{8}$$

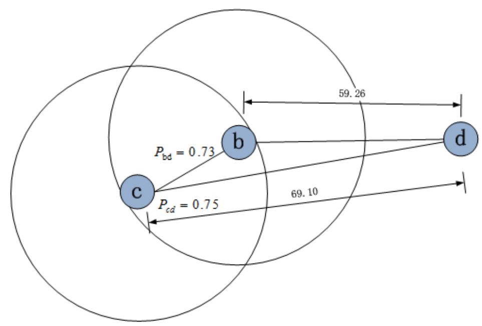

Figure 2 Distance priority criterion

In Figure 2, node c carries a piece of information to the destination node d. Probabilities of node b and node c to arrive at the destination node d are **Error! Reference source not found.**,**Error! Reference source not found.**. And their distances which are about arriving at the destination node d are **Error! Reference source not found.**,**Error! Reference source not found.**. When the node b and c established the connection, the information is sent through the b node.

Simulation and Results

In this section, I will introduce the configuration of the simulation environment, the key parameters of ADAF, and the final simulation results. In order to verify the performance of ADAF,it is compared with the existing Prophet algorithms in two aspects: successful deliver radio, overhead ratio.

Simulation Environment

In the simulation, two environment variables are set, one is set with time change, and second is set with the change of number of nodes. The details about the assignments of nodes are shown in Table 1.

Table 1 : The assignment of nodes

Group Name	Nodes Type	Nodes Range Inter-

face

A	Pedestrian	2-51	1
B	Pedestrian	54-63	1
C	Pedestrian	68-77	1
D	Pedestrian	80-89	1
E	Pedestrian	92-101	1
o	Bus	0-1	2
p	Bus	52-53	2
q	Bus	64-67	2
r	Bus	78-79	2
s	Bus	90-91	2
t	Taxi	102-111	2
S1,S2,S3,S4,S5,S6	Fixed station	112-117	1

The simulation time is set at least 24h, which is enough to in WDM verify the performance of the ADAF algorithm [10]. In WDM mode, the main parameters of the simulation environment are set as Table 2 .

Table 2 : The main parameters of pedestrian nodes

Parameters	Value	Parameters	Value
Network size	10000×8000	Simulation time	5 days
Network interface	Bluetooth	Buffersize	5 MB
Simulation place	Helsinki	btInterface range	10 m
btInterface speed	250k	highspeedInterface range	100 m
TTL	1433min	highspeedInterface speed	10 M
Number of groups	17	update time	1 s
Packet size	5 M	Interface type	Simple spray

We conducted five simulations of each protocol under the same environment and parameter setting, using one simulator to change the performance of the two algorithms.To verify that the performance of the ADAF is better than the traditional Prophet algorithm, I use the following two indexes: successful deliver radio, overhead ratio[11].

Delivery Ratio

Delivery radio refers to the probability of successful delivery of messages at a given time period [12]. The success radio of delivery is one of the important indexes to verify the performance of routing algorithms.

ADAF has a better delivery ratio than the traditional algorithm Prophet. In the scene with time change, the delivery ratio of ADAF algorithm is much better than Prophet. In the scene where the number of nodes varies, ADAF delivers better than Prophet(Figure. 3). As the number of nodes increasing, the overhead in the whole network increases exponentially, so the delivery rate is decreasing rapidly.

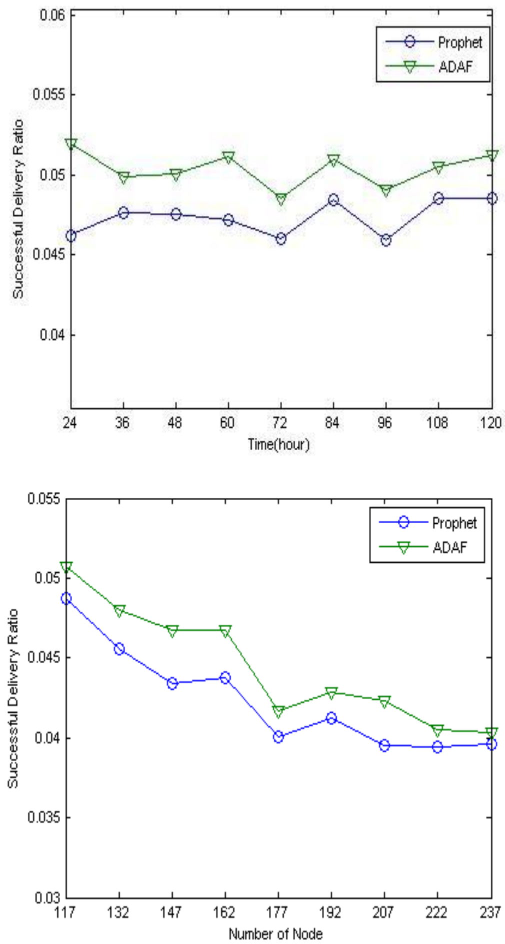

Figure 3 Comparisons of successful delivery ratio change over time and node density

The successful delivery ratio of ADAF is higher than Prophet over the process of 5 days. The results indicate that ADAF is more realizable in terms of message delivery ratio.

Overhead Ratio

The overhead ratio reflects the network load to some extent. A better routing algorithm should have lower overhead ratio. The ADAF algorithm is better than the Prophet in terms of overhead ratio, whether in scenarios that change over time or in scenarios that change with the number of nodes(Figure 4).

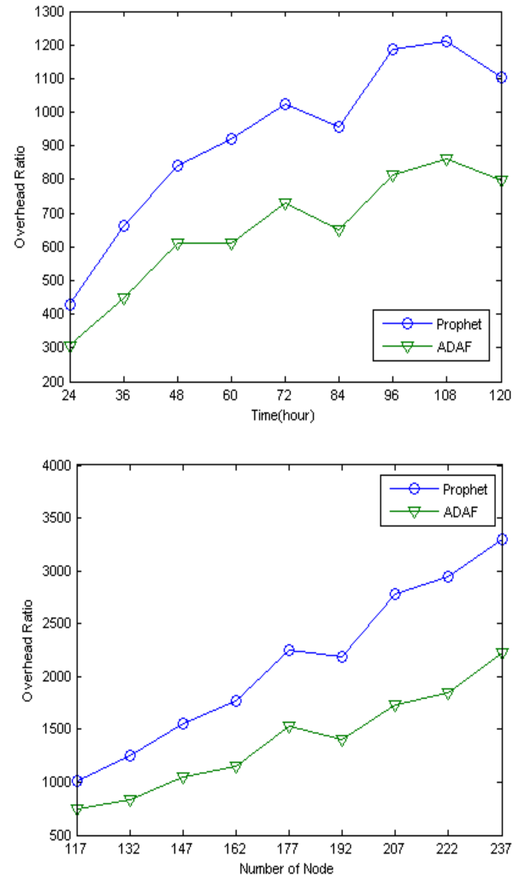

Figure.4 Comparisons of overhead ratio change over time and node density

Throughout the simulation time, ADAF performs better than Prophet in overhead ratio. This is likely that ADAF algorithm has dynamic aging factor, and the aging value of each node is greatly related to their own activity degree. As the number of nodes or time increasing, the overhead ratio on the entire network augments.

Conclusion

In this research, we have proposed a new routing algorithm named ADAF. With the frame work of ADAF, we implemented several operations to enable ADAF to dynamically distribute aging factors according to the active degree of nodes. In addition, we redefined the sending conditions of the message. We validate the effectiveness of the ADAF using WDM model by thorough simulation. The results indicate that our method is more suitable for urban environments than Prophet.

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References

[1] Wen-Zao Li, Feng Lin, Ji-Liu Zhou and Yan Wang. DTN Routing with Fixed Station Based on the Geographic Grid Approach in an Urban Enviroment, Wireless Pers Commun(2015) 82:2033-2049.

[2] Zhou,X.-W., Cheng, Z.-M., Ding, Y., Lim, J.-G., & Liu, Q.(2013).Dynamic DTN routing strategies based on knowledge. Wireless Personal Communications, 71(3), 1819-1836.

[3] Doering, M., Pögel, T. and Wolf, L. DTN routing in urban public transport systems. ACM, City, 2010.

[4] Ekman, F., Keranen, A., Karvo,J., & Ott, J. (2008). Working day movement model. In proceedings of the 1th ACM SIGMOBILE workshop on mobility models, ACM.

[5] Lindgren, A., Doria, A., & Schelen, O.(2003). Probabilistic routing in intermittently connneted networks. ACM SIGMOBILE Mobile Computing and Communications Review, 73(3), 19-20.

[6] Cao Pei, Qian Jiangbo, Chen Yefang, Chen Huahui . Merger-Based Subscription Query Transport Protocol in DTN. Telecommunications Science.2013.29(10):123-130.

[7] Tong Wang, Yue Cao, Yongzhe Zhou. A Survey on Geographic Routing Protocols in Delay/Disruption Tolerant Networks(DTNs), International Journal of Distributed Sensor Networks(Feb.2016).

[8] Anna Plazowska , VictorPapanek:Path of a Design Prophet [Review Article], Design Issues (Volume:32, Issue:4,Oct.2016), 97-98.

[9] Sneha Pathak, Nikhil Gondaliya, Nirav Raja, A Survy on PROPHET Based Routing Protocol in Delay Tolerant Network, 2017 International Conference on Emerging Trends & Innovation in ICT(ICEI).

[10] Keranen,A.,&Ott,J.(2007).Increasing reality for dtn protocol simulations .Helsinki University of Technology , Technical Report 2007.

[11] Bulut, E.,& Szymanski,B.K(2010).Friendship based routing in delay tolerant mobile social networks.In 2010 IEEE global telecommunications conference (GLOBECOM 2010).

[12] Mehto,A.,& Chawla,M.(2013).Comparing delay tolerant network routing protocols for optimizing L-copies in spray and wait routing for minimum delay .In Proceedings of the conference on advances in communication and control systems-2013 . Atlantis Press.