Global Journal of Computer Science and Technology: E
Network, Web & Security
Volume 17 Issue 3 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Valuable First Forwarding (VFF) Transmission Strategy for Epidemic Routing in Urban Environments

By Wenzao Li, Feng Lin, Xi Wu & Jiliu Zhou
Chengdu University of Information Technology

Abstract- The message queue mode in sending buffer of mobile node can impact the performance of Delay Tolerant Network (DTN). In urban environment, mobile nodes have a certain community-based movement feature, and which is related to time of day. The queue management of Epidemic routing can be improved in this environment, because some messages of a node are difficult to be transmitted to another community group within short contact time and limited transmission bandwidth. Some packets have not got a transmission opportunity when the Time To Live (TTL) of packets are exhausted. In order to make the messages delivery as much, the queue management in sending buffer becomes an important issue in DTN. The valuable message should be forwarded first, but how to define the value of a message? Therefore, we focus on improving the performance of Epidemic routing in urban environments and Valuable First Forwarding (VFF) transmission strategy in sending buffer is proposed. The TTL and message hops are jointly considered in this strategy, and the simulation results suggest that the VFF outperforms the random, FIFO and optimized MinHop (MH) queue mode in end-to-end path latency, delivery ratio and network overhead ratio.

Keywords: delay tolerant network, urban environment, queue management, transmission strategy.

GJCST-E Classification: B.7.2

VALUABLEFIRSTFORWARDING VFFTRANSMISSIONSTRATEGYFOREPIDEMICROUTINGINURBANENVIRONMENTS

Strictly as per the compliance and regulations of:

Valuable First Forwarding (VFF) Transmission Strategy for Epidemic Routing in Urban Environments

Wenzao Li [α], Feng Lin [σ], Xi Wu [ρ] & Jiliu Zhou [ω]

Abstract- The message queue mode in sending buffer of mobile node can impact the performance of Delay Tolerant Network (DTN). In urban environment, mobile nodes have a certain community-based movement feature, and which is related to time of day. The queue management of Epidemic routing can be improved in this environment, because some messages of a node are difficult to be transmitted to another community group within short contact time and limited transmission bandwidth. Some packets have not got a transmission opportunity when the Time To Live (TTL) of packets are exhausted. In order to make the messages delivery as much, the queue management in sending buffer becomes an important issue in DTN. The valuable message should be forwarded first, but how to define the value of a message? Therefore, we focus on improving the performance of Epidemic routing in urban environments and Valuable First Forwarding (VFF) transmission strategy in sending buffer is proposed. The TTL and message hops are jointly considered in this strategy, and the simulation results suggest that the VFF outperforms the random, FIFO and optimized MinHop (MH) queue mode in end-to-end path latency, delivery ratio and network overhead ratio.

Keywords: delay tolerant network, urban environment, queue management, transmission strategy.

I. Introduction

Delay Tolerant Network (DTN) is composed of isolated wireless sensors, the transmission path is unstable or changing over time. Routing is difficult in such environment due to the uncertain encounter-chance of mobile nodes. DTN is widely discussed in the challenged networks such as Military areas [1]and Civilian areas [2] . In the DTN architecture, the store-and-forward message routing method is employed to overcome communication disruptions. While the relay node selection methods are still important, a proper queue management needs also to exploit the precious contact opportunity to achieve a better network performance [3].

The movement features of mobile node are different in warier environments, it led to the routing design and queue management is not the same in different environment. With the appearance of smart devices equipped with several of sensors, DTN becomes more viable by using wearable smart devices in urban environment[4, 5]. Therefore, it is necessary to design a more suitable queue management than traditional queue mode in the urban environment. The contact time between two nodes is short in many circumstances, so not all the messages can be forwarded in the limited time period. Focusing on these problems, message order in sending buffer can be adjusted for performance optimized. The impact on the performance of DTN is difficult to determine when the queue mode is random forwarding, which has much randomness. In First In First Out (FIFO) queue management, the oldest will be forwarded first when the contact opportunity comes. The messages in sending buffer are come from one or more nodes in urban environment. Apart from its simplicity and the forwarding behavior don't consider the valuable of each message, this queue management is flawed severely. For example, a valuable message is received by a relay node, and the TTL of this message is running short. If the relay node meets the destination node, this message will miss this opportunity except the message just at the front of the queue. It is very likely that the massage had been aborted before the contact opportunity comes again.

We extend further the MinHop (MH) queue management proposed in [6] with environment consideration and performance enhancements. This paper has three main contributions. First, it presents a new queue management approach using a valuable message first forwarding. Second, we compare the effectiveness of Radom, FIFO, MH and VFF queue mode in urban scenario. The results shows that the VFF queue mode outperforms the Radom, FIFO, and MH in successful delivery ratio, network overhead ratio, and average delay in urban environment. Third, the forwarding approach includes a redundant removing strategy.

The remaining paper is prearranged as below: Section 2 describes the related work of VFF, and Section 3 describes the forwarding and removing strategy of VFF. In section 4, this paper gives the simulation

Author α: College of Communication Engineering, Chengdu University of Information Technology, Chengdu 610225, China.
Author σ: School of Computer Science, Sichuan University, Chengdu 610065, China.
Author ρ: College of Computer Science, Chengdu University of Information Technology, Chengdu 610225, China.
Author ω: College of Computer Science, Chengdu University of Information Technology, Chengdu 610225, China.
e-mail: zhoujl@scu.edu.cn

Global Journal of Computer Science and Technology (E) Volume XVII Issue III Version I Year 2017

parameters and queue mode comparing results, then this paper is concluded in Section 5.

II. Related Works

Urban environments are different from other environments for DTN application, and these differences caused by the nodes' movement. Therefore, traditional queue management approach cannot reach its potential in a particular environment. Generally different DTN applications require different performance indicators. Rodrigo P et al. in [7] proposed a street lighting system, and they focus on the efficient method in energetic terms and latency. In [8], Cardone G et al. put forward a data collection system in a urban environment, this solution require relative high delivery ratio in DTN. Hence, it is necessary for suitable queue management research in urban environment. The sensors are carried by people or fixed in vehicles, and the message transmit behavior only occur during the contact time. So the queue management approach should considerate the characteristic of person's encounter. The message forwarding approach is based on broadcasting in Epidemic routing protocol . With a large sending buffer, Epidemic can achieve a high performance rate [9]. Thus, the manage approach can impact on performance with sufficient buffer in DTN. Furthermore, the message will occupy almost the network resource without massage survival restriction [10]. The TTL mechanism aborts the message after a time period, the unfortunate queue management cause exhausted TTL in waiting transmission.

Generally, to perform an evaluation using social environment in DTN systems, the data trace of mobile sensor, deployment environment and the node's relationship among the participant should be needed [11]. In urban environment, Ekman F et al.[12] shows that the most people goes to work in the morning, spend their day at office for work, and go shopping or return their home in the evening for a familiar way. So, the encounter probability associates with the moment of a day. In urban environment, the most existing queue management approach, such as Random Queue Mode (RND), FIFO, and MH, are don't consider the message survival time and encounter probability. The each mobile node has some social skills to others, to sum up: 1. No motivation, 2. Low motivation, 3. High motivation. The nodes' motivation can be manifested by encounter numbers in urban environment (They are not the only example), and it can be assumed as Tab.1.

Table 1: A Example for Node A's Motivation in a Urban Scenario

Motivation Types	Encounter Times per day
No motivation	0~1
Low motivation	2~4
High motivation	More than 4

The packets should be forwarded by the encounter opportunity. Generally speaking, high motivation nodes are suitable for message carrier, but a meaningless forwarding would waste the TTL and waste an opportunity. Thus, a more suitable queue management for Epidemic routing in urban environment, VFF mode approach with the TTL and hop factors is proposed.

III. Valuable First Forwarding (VFF)Queue Mode

In this section, we introduce the VFF design and the removing strategy for DTN in Urban environment.

a) Transmission Characteristics in Urban Environments

The mobile nodes have social relationship, such as workmates, family, and classmates. The social relations among people can represent as the social graph [13], which is shown in Fig.1.

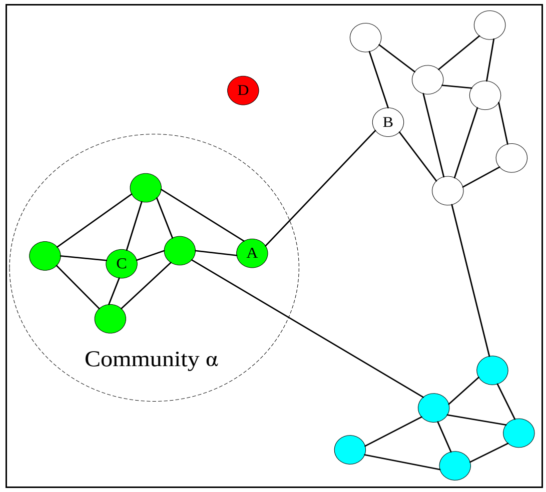


Fig.1: Illustration of community groups in a contact graph. Each color represents one group. The line between two nodes represent that the two nodes have contact relationship

There are many community groups in an urban environment, and some nodes of groups are able to contact other nodes which belong to the other groups. The Fig. 1 shows that, the community α have node A, which have contact with another group. Obviously, the same group nodes have frequent contact. According to Tab.1 for the classification of the nodes' social skill, the node D is No motivation type, the node C belongs to the High motivation type and the node A, node B is Low motivation type. There are many research papers using centrality metric for message forwarding [14, 15]. The contact probability depend on the topology of the contact graph, it cannot be represented the contact probability exactly to other nodes. Thus Gao et al. proposed a weighted social network model[16], The average contact probability between (i, j) is defined as formula 1, which obeys the Poison modeling of social networks.

$$C_i = 1 - \frac{1}{N-1} \sum_{j=1, j \neq i} e^{-\lambda_{ij} T} \tag{1}$$

Where, C_i indicates the average contact probability between node i and node j within time period T. N represents the nodes' number in DTN. This model is suitable in multicast routing environment and it is used for relay node selection. The higher centrality will be selected, such as node C in Fig.1. We assume that ϖ messages in node i could be transmitted in one contact chance with node j, and then a probability ξ_m, that the message m is forwarded, can be represented as (2)

$$\xi_m^{ij} = \frac{\varpi}{\kappa} - \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t} \tag{2}$$

Where the κ represent the messages in the sending buffer of node i. For $\tilde{t} = \{t_1, t_2, \cdots t_{\varpi}\}$ represent the survival time (TTL) of each message in node i, the $\tilde{t} \in (0, t)$ and the t represents the initial survival time of the message in DTN. Each pair of messages $\{m_{t'}, m_{t''}\}$ can be compared the delivery probability when the survival time meet the condition $(t' < t'')$. Thus, the probability difference equation for $m_{t'}, m_{t''}$ can be written as (3)

$$\xi(t'') - \xi(t') = \frac{\varpi}{\kappa} - \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t''} - \frac{\varpi}{\kappa} + \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t'}$$

$$= \frac{\varpi}{\kappa(N-1)} \sum_{j=1, j \neq i}^{N} \left(e^{-\lambda_{ij} t'} - e^{-\lambda_{ij} t''}\right) \tag{3}$$

Global Journal of Computer Science and Technology (E) Volume XVII Issue III Version I Year 2017

The $e^{-\lambda_{ij}t}$ is monotonically decreasing function when contact rate $\lambda_{ij} > 0$. Obviously, $\xi(t'') - \xi(t') > 0$. So the higher TTL value has a larger delivery probability in urban environment.

In urban environment, we start by classifying people motivation in three groups as Tab1. If some people are classmates or colleagues, they will repeat contact with limited range for longer time scales. These frequent contacts will cause some messages with relative higher hops number. Assuming that a message is forwarded many hops in the time point $t_1, t_2 \cdots t_n$, the probability density functions of $t_1, t_2 \cdots t_n$ are $f(t_1), f(t_2) \cdots f(t_n)$. $P(t_1 + t_2 + \cdots + t_n)$ can calculated through the convolution as Equation 4.

$$\mathrm{P}(t_1 + t_2 + \cdots + t_n) = \int_0^t f(t_1) \otimes f(t_2) \otimes \cdots \otimes f(t_n) dt \tag{4}$$

The condition $\mathrm{P}' > \mathrm{P}''$ is satisfied when $\mathrm{K} > M$, where the P'' represents the probability after K hops and the P' represents the probability after M hops. There are many repeat contact nodes in same group which it is frequent appearance in a narrow area, which is considered as a community in urban environment.

b) VFF Queue Management and Removing Strategy

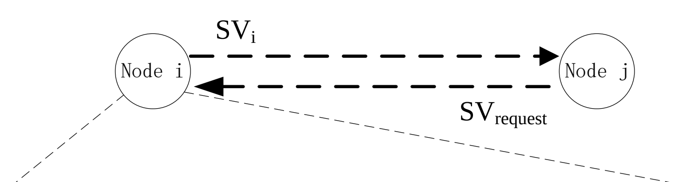
The messages are forward to other nodes which belong to the same community, we think this delivery behavior is insignificance. On the contrary, The No motivation or Low motivation type nodes, (e.g. node D or node A in Fig.1) which have less transmission opportunity, they should have some valuable messages to broadcast. The valuable behavior should broadcast messages to extensive regions in limited time. So we propose a method to measure the transmission value, in which the valuable message should be forwarded first. The forward processes are shown as blew:

Step 1: The message is added a field χ to record the hop times in the frame structure. The χ plus one when the message is forwarded once.

Step 2: When a contact opportunity occurs, then the messages will be rearranged by value calculation in sending buffer. It is calculated by Equation (5)

$$\psi_i = \alpha \frac{\tilde{t}_i}{\chi_i} \tag{5}$$

The Epidemic with VFF forwarding order is shown as the Fig. 2.



	Value	TTL remaining	Hops	Forwarding order
M1	7.33	22s	3	2
M2	22.5	45s	2	1
M3	5.14	36s	7	3
M4	3.84	50s	13	4

Fig.2: The forwarding order generated by calculation when the node i has a transmission opportunity

In Epidemic routing algorithm, The parties must exchange summery vectors (SV). After node j receives the SV_i which is represents the message summery vector of node i then node j will send the $SV_{request}$ to node i and $SV_{request}$ means that those messages not do not exist in sending buffer of node j. The $SV_{request}$ between node i and node j can calculate as Equation (6)[9]

$$SV_{request}^{ij} = \sum_{m=1}^{\mathcal{L}} M_m^j - \sum_{m=1}^{\mathcal{L}'} M_m^i \tag{6}$$

Then the message sending order by node i is shown as Fig.3

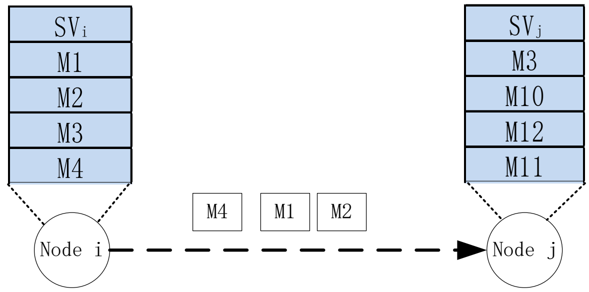


Fig.2: The forwarding order after summery vectors are exchanged between two nodes

Step 3: Removing redundant messages strategy: Each node builds a list T, it records those messages which already successful delivered to destination. When to nodes has a transmission opportunity they will exchange the T first. Then the two sides calculate the T by Equation (7).

$$\bar{T}_i = \complement_{T_i \cap T_j} T_i \qquad (7)$$

Where the $\bar{T}_i$ represents the complement set between set T_i and set $T_i \cap T_j$. It means that the record of $\bar{T}_i$ are successful delivery messages which does not exist in T_i before. Then the node i will delete the messages in sending buffer if it is exist in $\bar{T}_i$. When the update of list T is completed, the new list T' is set $(T_i \cap T_j)$.

Because there is no strategy on redundant message control in Epidemic routing, and the intermediate state nodes still forward the redundant messages. Obviously, the removing strategy can decrease the network overhead ratio in DTN.

IV. Simulation and Results

In this section, the simulation environment, key parameters and the simulation results are introduced. In order to verify the performance of VFF queue management strategy, it is compared with other queue management methods:

1. Random: The message in sending buffer will be random selected to transmission to neighbor node.
2. FIFO: In this mode, all messages are arranged according to in coming arrival time. When transmission opportunity appears, the oldest messages will be transmitted first.
3. MH: The hops number will be recorded in the sending buffer. When forwarding opportunity arises, the minimal hops message will be transmitted first [6].

We observed several key indicators from two aspects, the indicators change with the increased node density and buffer size.

a) *Simulation Environment*

Frans et al. propose a movement model named Working Day Movement (WDM) Model [12], and it shows that average person goes to work in the morning, spends their day in office, and goes shopping or returns their home in the evening. Furthermore, the encounter features is associated with daily routines of people. This movement feature model accords with the realistic situation. For this purpose, we set three types mobile nodes in the simulation scenario, it includes pedestrian node, buses node and taxies node. We had ranging from 70-270 mobile nodes moving on a map of Helsinki centre area. These nodes move regularly to position of home, offices and shops, which is controlled by the WKT data files, which is provided by The Opportunistic Network Environment simulator (The ONE) [17]. All mobile nodes are restricted in a rectangular (10000m*8000m). There are two types interface in the simulation, one is low speed interface with 100kbps and 10m transmitting range, another is high speed interface with 10Mbps and 100m transmitting range, and they are equipped in buses and taxies. The other details about the assignments of nodes are listed in Tab.2.

Table 2: The assignment of nodes, interfaces and positions to the different groups

Groups	Type	Nodes	Interface
A ,B,C,D,E	Pedestrian	10~50 for each	1
o,p,q,r,s	Bus	2 for each	2
T	Taxi	10	2

The simulation time is set 12 hours, which can show the movement regular during the day. We observed the message interaction process, it partly indicates the motivation level in urban environment and it is shown as Fig.3.

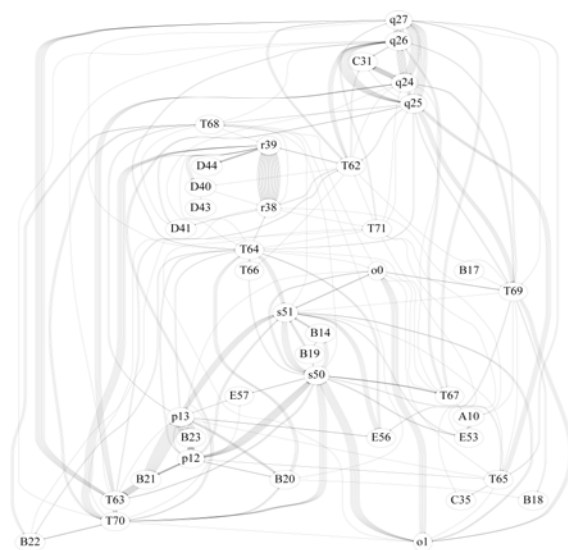


Fig.3: The packets passing process in a urban scenario (with help from Graphviz)

As it is shown in Fig.3, node B14 and node B19 are frequent communication. We think the value of their most messages are low in Epidemic routing, it should be set to lower priority in queue mode. In addition, it meets our assumptions about the node social skills classification. Some nodes contact frequently, some nodes are not so active, and some nodes imply transmission inertia.

We set a urban scenario as real as possible in order to verify the effectiveness of the VFF approach, and we ran the simulations for each queue mode several times under the same scenario and parameter setting using the ONE simulator:(Tab.3)

Table 3: Key simulation parameters

Parameter	Value
World Size	10000m*8000m
Simulation Time	43200 seconds
City Scenario	Helsinki
Buffer Size	4M~20M
Message TTL	400 seconds
Message Size	50k,100k
Movement Model	WDM(Pedestrian), Bus Movement(Bus), ShortestPathMapBasedMovement(Taxi)

To validate that the VFF outperforms the existing the queue mode Random, FIFO and MH in urban environments, we use the following three metrics: successful delivery rate, network overhead ratio and average delivery latency. Moreover, we observed the change of node density and buffer size impact on performance.

b) Successful delivery ratio

The delivery ratio is the ratio of the successful delivered to the destination within given time period, and it is an important indicator for DTNs.

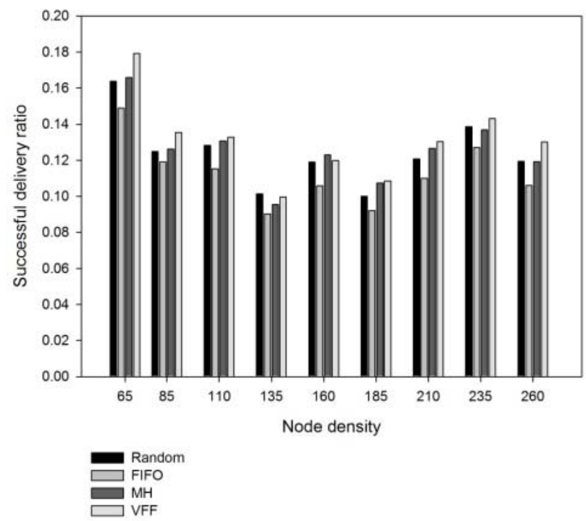


Fig.4: Comparisons of successful delivery ratio under the increasing node density

From Fig.4, the result shows that FIFO queue mode performs worse in this scenario, and the Random queue mode has certain uncertainty. VFF approach had a better delivery ratio than others except under 135 nodes and 160 nodes scenario. Upon the whole, VFF is superior to the Random, FIFO and MH in urban environments.

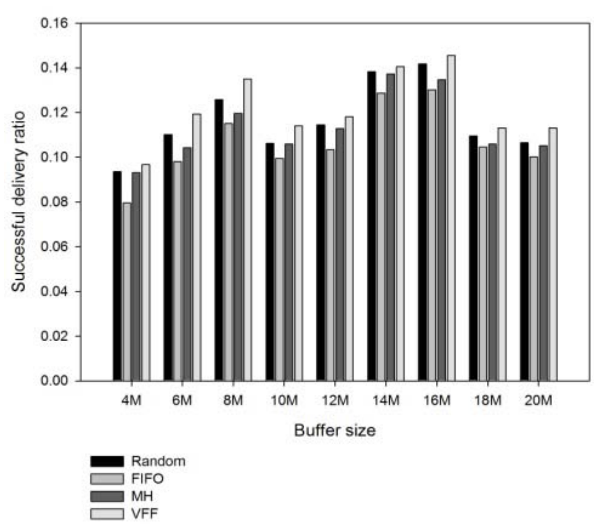


Fig.5: Comparisons successful delivery ratio under the increasing sending-buffer size

VFF is better than the other queue mode with different node buffer size (Fig.5). Likewise, the FIFO has poor performance of delivery ratio. FIFO is influenced by the mechanic, and ossified handling way in urban environments.

c) Network overhead ratio

The network overhead ratio can reflect the network load to some extent. The lower value of overhead ratio indicates the better delivery efficiency. The overhead ratio δ is defined as Equation (8).

$$\delta = \frac{\sum_0^t \varphi - \sum_0^t \omega}{\sum_0^t \omega} \tag{8}$$

Where φ represents the successful transmitting times, and ω is successful delivery times.

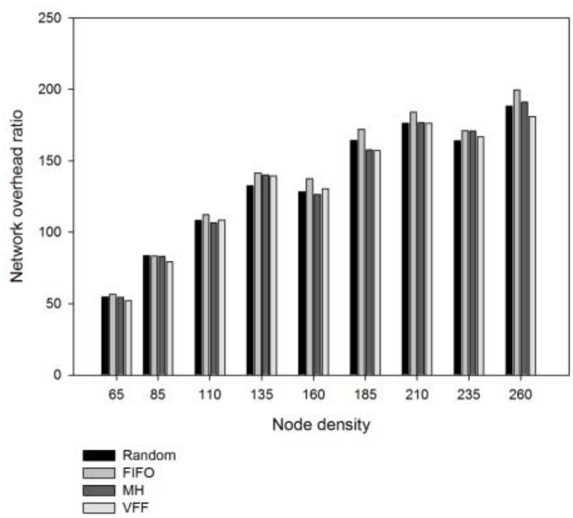


Fig.6: Comparisons of network overhead ratio under the increasing node density

Fig.6 shows that VFF does not have an absolute advantage in different density with the overhead ratio. This result is caused by the uneven node density. Despite such randomness interference exists, VFF general superior to others, and it is acceptable in DTNs.

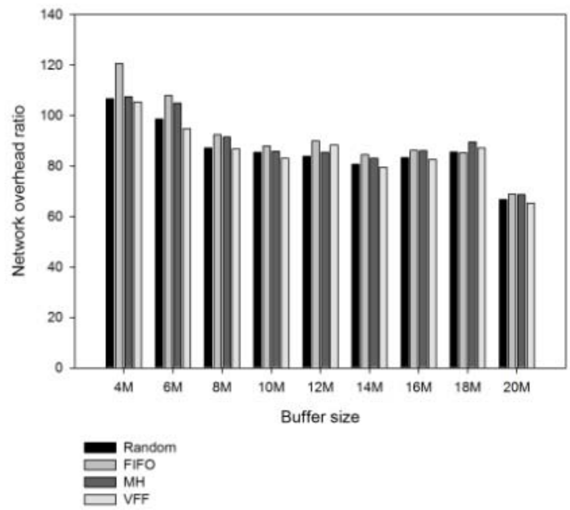


Fig.7: Comparisons of network overhead ratio under the increasing sending-buffer size

Likewise, the performance of VFF strategy is not significantly better than other methods in different buffer size. VFF approach is clearly better than FIFO and MH at low buffer size area (4M~10M). Network overhead ratio shows decreasing trend with the increasing sending buffer, and it represents the DTN delivery efficiency. Each queue management method result in smaller gaps of overhead ratio and delivery ratio, this is due to the limited impact of queue management in Epidemic algorithm.

d) Average latency

Average latency is the average time with message time consumption during source-to-destination path. The source-to-destination average latency is desired for short value in DTN design.

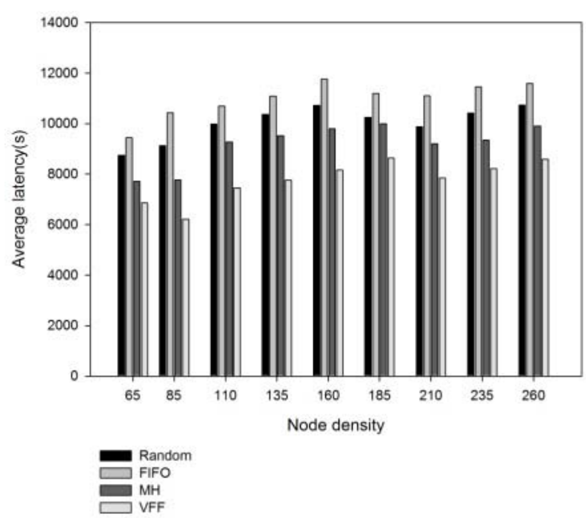


Fig.8: Average latency under the node density increasing

It is clear that in Epidemic routing, VFF queue management is superior to other methods at deferent node density (Fig.8). Because these queue modes are in the same urban scenario, the VFF's lower value of average latency and higher value delivery ratio suggest that VFF selects the more correct messages to transmit first than the others.

Global Journal of Computer Science and Technology (E) Volume XVII Issue III Version I Year 2017

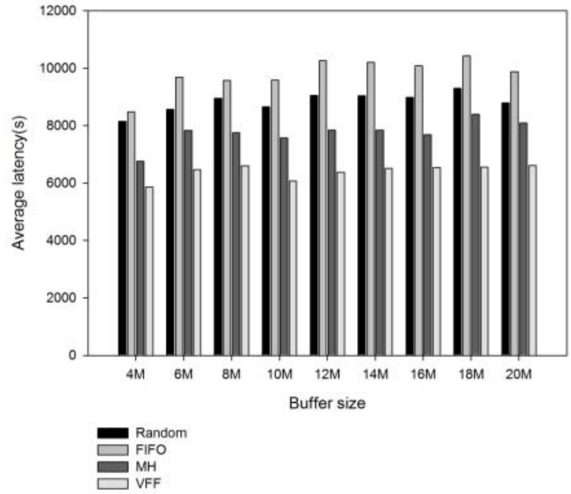


Fig.8: Average latency under the sending-buffer size increasing

Moreover, we observe the average latency at different sending buffer size, VFF still show up better performance than other queue mode.

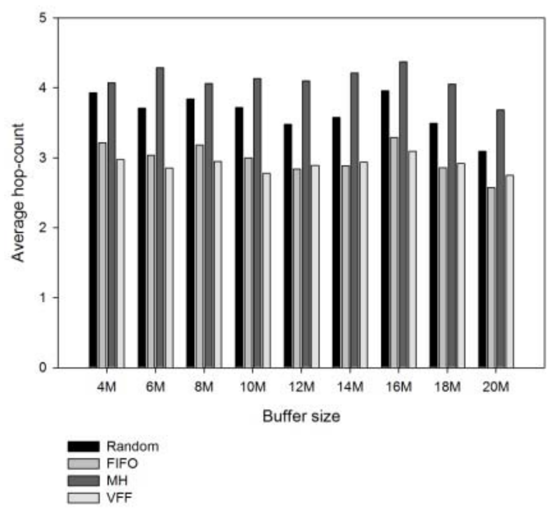


Fig.9: Average hop-count under the sending-buffer size increasing

From Fig.9, VFF has certain advantages on average hops. The message average hop-count represents the messages forwarded status around the network, and the higher value of hop-number reflects that the message is forwarding frequently. Assuming under the same delivery ratio, the smaller hop-number showed more efficient forwarding behavior for messages.

V. Conclusion and Prospects

The suitable queue mode strategy for Epidemic routing in urban environment is currently, one of the valuable topics in DTN design. In this paper, we propose a forwarding strategy named VFF that optimizes the Epidemic routing in urban environment. The nodes movement feature and social character are jointly considered in this proposed queue management strategy. In such challenging network environment, the most valuable messages should be forwarded fist on the precious encounter chance. There will be more and more DTN applications in urban environment with the increasing low price of smart devices and sensors, such optimized strategy conducive to DTN application design. In future research work with the queue management, we would focus on the message valuable function design, which can get better performance with Epidemic routing in urban environment.

Global Journal of Computer Science and Technology (E) Volume XVII Issue III Version I Year 2017

VI. Acknowledgements

The authors would like to thank the persons who review and give some valuable comments to improve the paper quality. This work is also supported by Natural Science Foundation of China (no.61272448), Doctoral Fund of Ministry of Education of China (no.20110181130007), Science and Technology Supporting Plan of Sichuan (nos. 2011RZ0004 and 2012GZ0005), Soft Science Found of Science and Technology Department of Sichuan (no.2014ZR0146).

References Références Referencias

1. Caini, C., et al., *Delay-and disruption-tolerant networking (DTN): an alternative solution for future satellite networking applications.* Proceedings of the IEEE, 2011. **99**(11): p. 1980-1997.
2. Hur, J. and K. Kang, *Secure data retrieval for decentralized disruption-tolerant military networks.* IEEE/ACM Transactions on Networking (TON), 2014. **22**(1): p. 16-26.
3. Lenas, S.-A., et al., *Queue-management architecture for delay tolerant networking*, in *Wired/Wireless Internet Communications*. 2011, Springer. p. 470-482.
4. Caini, C., et al. *DTN meets smartphones: Future prospects and tests*. in *Wireless Pervasive Computing (ISWPC), 2010 5th IEEE International Symposium on*. 2010. IEEE.
5. Teranishi, Y. and S. Shimojo. *MONAC: SNS message dissemination over smartphone-based DTN and cloud*. in *Peer-to-Peer Computing (P2P), 2011 IEEE International Conference on*. 2011. IEEE.
6. Ayub, Q., S. Rashid, and M.S.M. Zahid, *MinHop (MH) Transmission strategy to optimized performance of epidemic routing protocol.* Global Journal of Computer Science and Technology, 2011. **11**(9).
7. Pantoni, R., C. Fonseca, and D. Brandão, *Street Lighting System Based on Wireless Sensor Networks.* 2012.
8. Cardone, G., et al. *Effective collaborative monitoring in smart cities: Converging MANET and WSN for fast data collection*. in *Kaleidoscope 2011: The Fully Networked Human?-Innovations for Future Networks and Services (K-2011), Proceedings of ITU*. 2011. IEEE.
9. Vahdat, A. and D. Becker, *Epidemic routing for partially connected ad hoc networks*. 2000, Technical Report CS-200006, Duke University.
10. Abdulla, M. and R. Simon. *Controlled epidemic routing for multicasting in delay tolerant networks*. in *Modeling, Analysis and Simulation of Computers and Telecommunication Systems, 2008. MASCOTS 2008. IEEE International Symposium on*. 2008. IEEE.
11. Miklas, A.G., et al., *Exploiting social interactions in mobile systems*. 2007: Springer.
12. Ekman, F., et al. *Working day movement model*. in *Proceedings of the 1st ACM SIGMOBILE workshop on Mobility models*. 2008. ACM.
13. Zhu, Y., et al., *A survey of social-based routing in delay tolerant networks: positive and negative social effects.* Communications Surveys & Tutorials, IEEE, 2013. **15**(1): p. 387-401.
14. Daly, E.M. and M. Haahr. *Social network analysis for routing in disconnected delay-tolerant manets*. in *Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing*. 2007. ACM.
15. Hui, P., J. Crowcroft, and E. Yoneki, *Bubble rap: Social-based forwarding in delay-tolerant networks.* Mobile Computing, IEEE Transactions on, 2011. **10**(11): p. 1576-1589.
16. Gao, W., et al. *Multicasting in delay tolerant networks: a social network perspective*. in *Proceedings of the tenth ACM international symposium on Mobile ad hoc networking and computing*. 2009. ACM.
17. Keränen, A., J. Ott, and T. Kärkkäinen. *The ONE simulator for DTN protocol evaluation*. in *Proceedings of the 2nd international conference on simulation tools and techniques*. 2009. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

This page is intentionally left blank