Cooperative willingness perception based routing algorithm in opportunistic network

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Abstract. There is a cooperative willingness perception based routing algorithm is proposed in this paper. The average duration of messages forwarding is utilized to measure the cooperative willingness between nodes; moreover，combining with the parameter of contact probability between nodes, the relay node can be selected reasonably. Further, in order to maximize the utility of network resources, message priority is considered. Results show that the proposed algorithm can effectively improve network performance.

1. Introduction

In recent years, in order to solve the problem of data communication between the nodes in wireless network under intermittent connection environment, the researchers proposed the concept of "opportunistic networks" [1], The network utilizes the communication opportunities arising from node movement to achieve data transfer between nodes based on the routing mode of storing–carrying–forwarding, but ignoring exhibited different cooperative willingness by rational entity controlled (such as a person or special institution) in the practical application.

Existing related research shows that different cooperative willingness between nodes will not make opportunistic networks routing algorithm to run effectively, which have a significant impact on network performance. Ref. [2] utilized the mathematical model of opportunistic networks to analyze and compare the relationship between the performance of Epidemic [3], Spray and Wait [4] and Two-Hop [5] the 3 kinds of algorithms and cooperative willingness between nodes in non-cooperative environment. The results showed that the overhead of Epidemic are greatly influenced by the node cooperative willingness, while the time delay of Spray and Wait are greatly influenced by the node cooperative willingness.

For non-cooperative behavior of nodes, mainly on how to effectively detect and punish non-cooperative nodes as well as design related coordination incentive mechanism, however, does not take into the characteristics of opportunistic networks and different cooperative willingness between users in practical application.

Due to the connection of nodes in opportunistic networks in line with "the theory of six degrees of separation", and contact strength will differ by familiarity with each other. In summary, research node collaboration problem in opportunistic networks to improve network performance and realize network deployment is necessary.

2. Perceived cooperative willingness

The key to design efficient routing algorithm is to "choose the best forwarding node and the best forwarding time". Due to the different cooperative willingness between nodes under actual circumstances, and nodes have social attributes and makes them more willing to contact their own social ties to provide services, so the cooperative willingness intend to include the forwarding node selection process selection will more accord with the practical application requirements of opportunistic networks.

The case of considering the cooperative willingness and encounter probability, compared to the

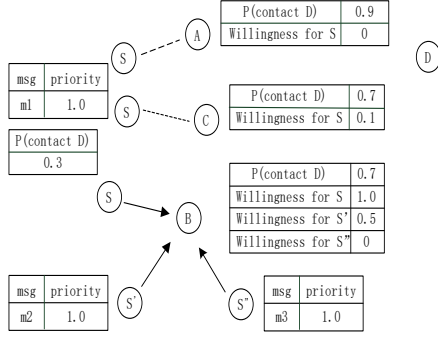node A and node C, node B is more suitable as message forwarding node of node S, as shown in Fig.1.
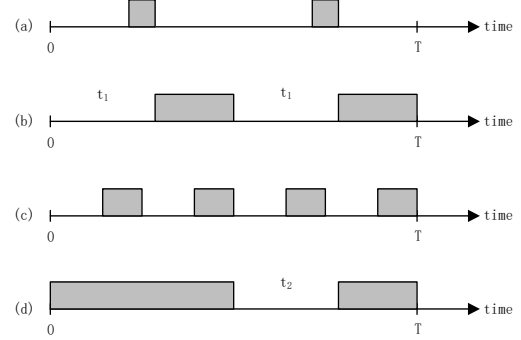

Fig.1 Example of node cooperation

Fig.2 Different contacts between node i and node j

Fig.2 is a schematic view of node i and node j in different situations to meet. It is seen from the Fig.2, by using nodes' encounter frequency or average interval encounter time cannot accurately estimate the strength of social connection, and cooperative willingness between nodes also cannot effectively quantify.

In order to reflect cooperative willingness more reasonable and accurate, in this paper, we introduce a new metric——Average Forwarding Time (AFT) of message, defined as

$$AFT_{ij} = \frac{T_{window}}{\sum_k N_{t_k, t_{k+1}}}$$

(1)

As shown in Equations (1): T_{window} is training time window, represents the time interval between two node status updates; $N_{t_k, t_{k+1}}$ indicates the number of messages that node i forwards for node j in two encounter time interval $t_{k+1} - t_k$. Then reuse Gaussian likelihood function for Equations (2) on normalized processing, whereby the cooperative willingness which node i for node j as

$$w_{ij} = \exp(-\frac{AFT_{ij}^2}{2\sigma^2})$$

(2)

As shown in Equations (2): σ is scaling constant.

3. Routing algorithm principle

This paper presents a cooperative willing aware routing (CWAR) in opportunistic networks, which comprehensive considering the communication opportunity and cooperative willingness between nodes. Assumptions of the algorithm are as follows.

1) Node cache space for the message self-generated is infinite, while for other nodes forwarded message is limited;

2) Only to unicast communication between nodes and their link is bidirectional;

3) Nodes in the network are rational, that is not exist node which attacked malicious (DoS, the black hole attack, etc.).

3.1 Fundamental

1) When node i meet node j, firstly by descending order of the message priority send messages when encounter is the destination node, and exchange their respective willingness values at the same time;

2) If cooperative willingness value that node i received from node j is greater than the threshold w_{th}, node i send summary vector information of message corresponding in its cache to node j, otherwise don't send;

3) According to the summary vector information, node j recalculate the priority and their corresponding delivery probability of each message, then these information were returned to the node i;

4) According to delivery probability and priority related information, node i determine the set of

messages to be forwarded, and by every byte descending selfish gains to send a message in case of link capacity is limited;

5) After received the message sent by node j, node i will store the message according to priority. Similarly, node j also performed according to the above process.

3.2 Delivery probability estimation

Each node maintains an encounter probability table, which records the encounter probability of the current node with other nodes. When node i is meeting node j, its value is updating according to Equations (3).

$$P(i, j) = P(i, j)_{old} + (1 - P(i, j)_{old}) \times P_{init} \tag{3}$$

As shown in Equations (3): $P_{init} \in (0,1]$ is an initial constant, $P(i, j)_{old}$ represents the probability that node i and j last met. If two nodes have not met for a period of time, the delivery probability will gradually decay, calculated as

$$P(i, j) = P(i, j)_{old} \times \gamma^k \tag{4}$$

As shown in Equations (4): $\gamma \in (0,1]$ is a attenuation constant, k is the number of time units since the last encounter elapsed, time unit is determined by the different application situation and the network delay.

3.3 Message Priority Calculation

This paper uses a cache management strategy based on the message priority level, that is, when node i received the message from previous hop node $(i-1)$ sent, the message priority according to Equations (5) was calculated.

$$p_i = p_{i-1} \times w \tag{5}$$

As shown in Equations (5): p_i and p_{i-1} respectively represents the priority of message in the current node i and the previous hop node $(i-1)$; w represents the cooperative willingness that the current node i to the previous hop node $(i-1)$.

This article defined the own gain when node i forwards the message m to node j as

$$g = p \times \Delta P_{delivery} \tag{6}$$

As shown in Equations (6): g represents own gain; p represents the priority of message m in node j; $\Delta P_{delivery}$ represents the delivery probability increment of the message m obtained. The byte unit revenue can be expressed as

$$\Delta(m) = \frac{g}{s(m)} \tag{7}$$

$\Delta(m)$ represents the byte unit revenue; $s(m)$ represents size of message m.

4. Result analysis

This paper adopts opportunistic network environment (ONE) [6] to verify related performance, it choose the improved Epidemic algorithms and PRoPHET algorithm as a comparative object, and assuming that nodes in these two algorithms will not forward the message to not collaboration node, the cooperative willing threshold value is $w_{th} = 0.3$.

Fig.3 shows the message delivery rate of success in these three kinds of algorithms in different size of node's cache. It is seen from the Fig.3, with the increase of the cache, delivery rate of the three kinds of algorithms are increased. Meanwhile, the message delivery rate of success of CWAR algorithm than of C-Epidemic algorithm and of C-PRoPHET, increased by about 15%.
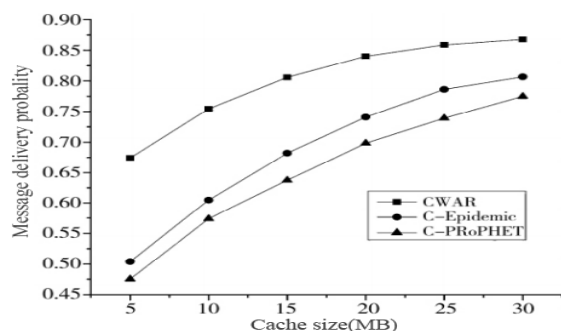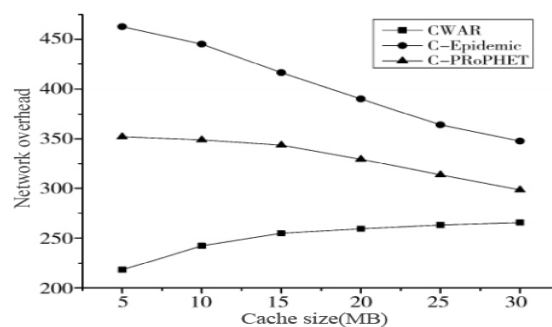
Fig.3 Message delivery probability   Fig.4 Network overhead

Fig.4 shows the relationship between the network overhead rate and the node's cache. It is seen from the Fig.4, the overhead rate of C-Epidemic algorithm is the largest, and the overhead rate of CWAR algorithm is the least. In addition, the network overhead rate of C-Epidemic algorithm and of C-PRoPHET are greatly influenced by the cache, while change of the overhead rate of CWAR algorithm is relatively stable.

5. Conclusion

This article proposed CWAR algorithm, the algorithm fully take the cooperative willingness and contact opportunity into account when selecting the next hop forwarding node, at the same time, because of the cache and link capacity are limited, so message forwarding process uses unit byte income as the main basis. The simulation results show that CWAR algorithm effectively improve message delivery success rate and network overhead.

Acknowledgement

References

[1] WU Da-peng, ZHANG Hong-pei, WANG Hong-gang, et al. Quality of protection driven data forwarding for intermittently connected wireless networks[J]. IEEE Wireless Communications, 2015, 22(4): 66-73.

[2] KARALIOPOULOS M. Assessing the vulnerability of DTN data relaying schemes to node selfishness[J]. IEEE Communications Letters, 2009, 13(12): 923-925.

[3] VAHDAT A, BECKET D. Epidemic routing for partially connected ad hoc networks[J]. 2000: 853-862.

[4] SPYROPOULOS T, PSOUNIS K, RAGHAVENDRA C S. Spray and Wait: An efficient routing scheme for intermittently connected mobile networks[C]// ACM. Proceedings of the 2005 ACM SIGCOMM workshop on Delay Tolerant Networking. Philadelphia: ACM Press, 2005: 252-259.

[5] ALHANBALI A, NAIN P. Performance of Ad-hoc Networks with Two-Hop Relay Routing and Limited Packet Lifetime[J]. Performance Evaluation, 2008, 65(6): 463-483.

[6] KERANEN A, OTT J, KARKKAINEN T. The ONE simulator for DTN protocol evaluation[C]// ICST. Proceedings of the 2nd international conference on simulation tools and techniques. Italy: ACM Press, 2009: 315-326.