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A Routing Protocol for Delay-tolerant Networks

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ABSTRACT: Epidemic algorithm improves the delivery rate by generating a large number of copies of the message. It is easy to implement and obtain high delivery rate. However, DTN network is usually memory-and-bandwidth-limited. The copy and distribution of message without limitation lead to the decrease in network performance. The proposed ANEpidemic algorithm reduces the invalid replication of message by utilizing position and angle information of relay nodes. Simulation results show that the proposed algorithm has a better performance in delivery rate and end-to-end delay.

Keywords: DTN; position; routing; single-copy; multi-copy

1 INTRODUCTION

Due to its characteristics such as long communication delay, high dynamic topology, sparse distribution of nodes and frequent link break, routing are the key issues of research in delay-tolerant networks (DTN).

Source nodes do not establish a complete route to destination nodes to send data packets. The relay node receives packets, stores them and then finds the destination or a better relay node to forward packets. Through the hop-by-hop storage-carry-forward strategy, packet will finally reach the destination nodes. In the storage-carry-forward process, routes are constructed by considering the characteristics of the DTN. Although DTN topology is frequently changing, nodes within local area may be strongly connected in a short time and thus can provide a path from source or relay nodes to destination or better relay nodes.

In other words, a link is established between the pair of nodes whenever they encounter. This link is time-sensitive that it is only valid for the duration when the nodes are in range of one another [1].

In the classical DTN protocols such as Direct Delivery [2] and First Contact [3], only single-copy of each message exists in the network.

In Direct Delivery, the node carries messages until it meets their final destination. In First Contact routing, the nodes forward messages to the first node they encounter, which results in a "random walk" search for the destination node. Single-copy schemes have lowest overhead but are not so good in packet delivery [4] [6].

These observations motivated routing protocols, such as Epidemic [7], PRoPHET [8] and MaxProp [9] which take into account number of message copies and try to calculate utility of candidate nodes using history-based or global-knowledge.

The epidemic routing [8] has been proposed as an approach for routing in sparse and/or highly mobile networks in which there may not be a contemporaneous path from source to destination. It adopts a so-called ''store-carry-forward'' paradigm – a node receives a packet buffers and carries that packet as it moves, passing the packet on to new nodes that it encounters. Being analogous to the spread of infectious diseases, each time a packet-carrying node encounters a node that does not have a copy of that packet, the carrier is said to infect this new node by passing on a packet copy; newly infected nodes, in turn, behave similarly[10][11].

The destination receives the packet when it first meets an infected node. When the traffic load is very low, epidemic routing is able to achieve minimum delivery delay at the expense of increased use of resources such as buffer space, bandwidth, and transmission power. However, this also leads to link and/or storage congestion when the network is loaded.

Variations of epidemic routing have recently been proposed that they exploit the tradeoff between delivery delay and resource consumption.

PRoPHET [8] tries to estimate which node has the highest likelihood of being able to deliver a message to the final destination based on node encounter history.

MaxProp [9] floods the messages but explicitly clears them once a copy gets delivered to the destination with message delivery probabilities.

Since the Epidemic algorithm uses flooding mechanism, its efficiency is high while its delay is short when small amount of messages and sufficient resources in the network. However, it lacks judgments and choices about next hop nodes of a message, resulting in a large quantity of copies in the network which leads to a lot of redundancy. In an actual network, the resources of nodes are often limited; therefore, messages cannot be completely exchanged; besides, excessive redundancy has a great impact on network performance.

In this paper, we propose a routing protocol that uses angle and position information of local node to

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control the duplication of message.

The resulting protocol is referred to as the ANEpidemic routing protocol. The performance of proposed protocol is compared with related works. Simulation shows that our scheme performs better in terms of delivery probability, delay and overhead.

The remainder of this paper is organized as follows. In Section 2, we develop the protocol. Simulation results are presented in Section 3. Conclusion is in Section 4.

2 THE PROPOSED PROTOCOL

Epidemic routing [8] works as an approach for routing in sparse or mobile networks. There may not be a contemporaneous path from source to destination. Store-carry-forward is adopted.

A node receives a packet, buffers and carries that packet as it moves, and passes the packet on to new nodes that it encounters. Being analogous to the spread of infectious diseases, each time a packet-carrying node encounters a node that does not have a copy of that packet, the carrier is said to infect this new node by passing on a packet copy; newly infected nodes, in turn, behave similarly[12][13].

The destination receives the packet when it first meets an infected node. When the traffic load is very low, epidemic routing is able to achieve minimum delivery delay at the expense of increased use of resources such as buffer space, bandwidth, and transmission power [14]. However this also leads to link and/or storage congestion when the network is loaded [15].

Aimed at disadvantages pointed out by above analysis which Epidemic routing algorithm has, we propose restriction on message flooding which could make messages have a greater probability to be delivered successfully with the help of message copies generated after the restriction.

This is to add judgments to the node selection; if it complies with the judgment condition, then it delivers message to the node; otherwise, it does not.

When a node meets a new node, if the node is nearer the destination node than others, it may be with high probability to meet the destination node.

In another word, if next hop of the node is towards destination, the node has high probability to meet the destination node. This is judged by the angle of the moving node. If these conditions are satisfied, duplication message will be copied to the new node, otherwise, it will not be.

In this paper, we propose a routing protocol that uses angle and position information of local node to control the ineffective duplication messages.

We select next hops of messages through judgments of relative positions between nodes (The node which is carrying message and the node that will relay the message to the destination node).

The closer a node is to the destination node, the greater probability of it may meet the destination by stochastic motion. The node carrying message is regarded as the center of a circle, and the spreading range of the node is regarded as its radius. Select nodes in the semicircle which are closer to the destination node as the next hop of messages.

When nodes carrying messages meet their neighbors, in addition to the basically connective judgments, and when the angle between the nodes is less than 90°, they deliver the massage; otherwise, they do not. An angle which is less than 90° means that the direction of message roughly forwarding heads to the destination.

The success rate of message delivery will be increased after this selection. By ignoring nodes that have lower probability of message delivery, the proposed protocol saves network resources.

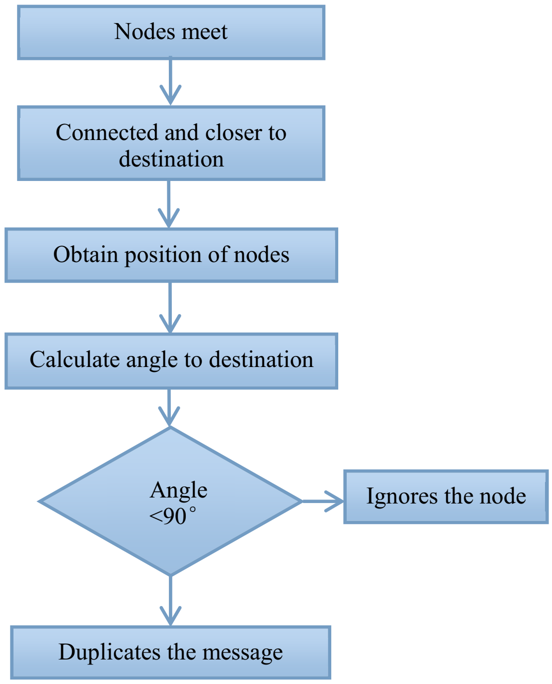


Figure 1. Process of duplication message.

When a node encounters new nodes, it will calculate angle of each nodes. If it is less than 90 degrees to the destination node, messages will be copied to the new node; otherwise, it is not for messages. Figure 1 shows the diagram of ANEpidemic algorithm.

3 SIMULATION RESULTS

In order to observe performance variation of DTN routing protocol which was affected by memory size and number of nodes, we performed simulations in ONE 1.41 simulator.

3.1 *Simulation parameters*

Table 1 summarizes the measurement parameters.

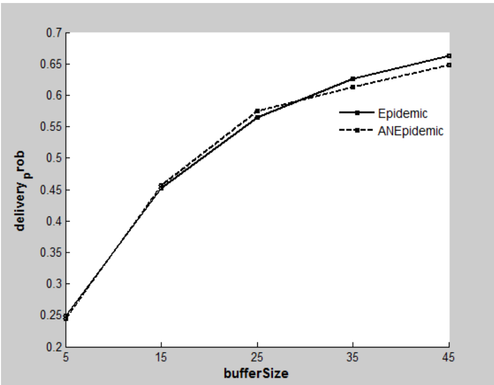
Table 1. Measurement configuration

Parameters	Values
Number of nodes	200
Simulation time(h)	12
Node speed(m/s)	0.5-3
Buffer size(M)	0-45
Range (m2)	4500*3400
TTL(h)	5
Routing protocol	Epidemic, ANEpidemic
Event generators (s)	5-25

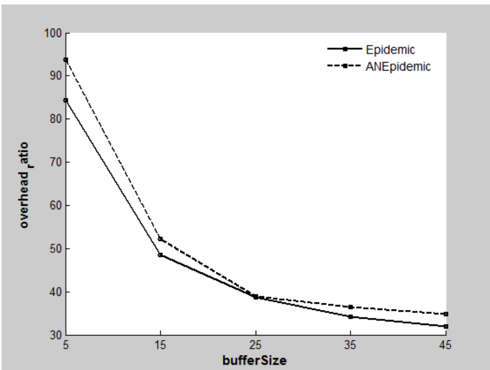
3.2 *Varying memory size*

With 125 nodes randomly displaced, the messages are sent between the randomly chosen sources and the destinations at generation rate of 1 packet every 5s-35s.

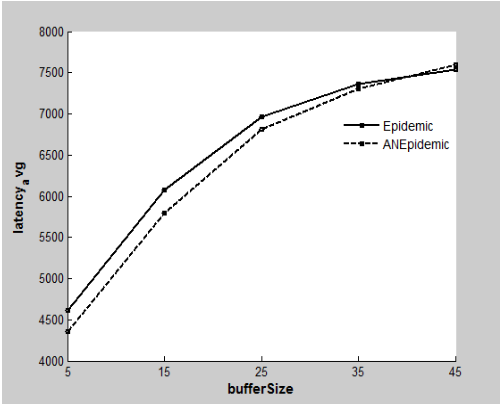
Buffer size determines the number of messages that a node can carry. With very small memory size, the stress of memory requirement is relatively heavy.



(a) Delivery probability



(b) Overhead ratio



(c) Latency

Figure 2. Performance of varying memory size.

As shown in Figure 2(a), Delivery probability of both protocol increases when the size of buffer increases. ANEpidemic algorithm performs better, when the buffer reaches 35M for the speed of the message generation, the cache size is not the key factor.

Then the Epidemic algorithm has a better performance by generating a large number of copies. The delivery probability is a little lower than ANEpidemic due to the limitation in node angle.

The routing overhead of both algorithms decreases with the increase in buffer size, as shown in Figure 2(b) Due to the increase in cache size, its capabilities of carrying and forwarding are improved. A node can handle more packets of information under the same conditions, thus, it can reduce the network overhead.

As shown in Figure 2(c), with the increase in buffer size, the average end-to-end delay is also increased. The increasing buffer size of node will increase the capacity of storage and carry the messages. What's more, this will also increase the delay.

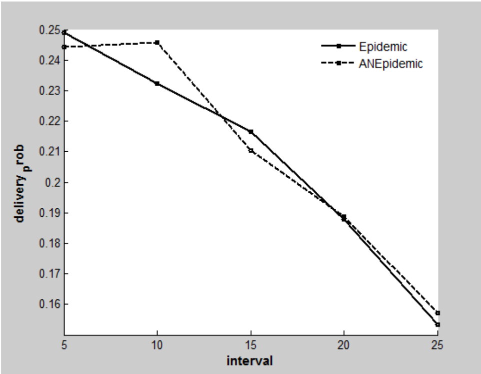
Therefore, as the buffer size is increased, the size of the delay is also increased. ANEpedemic has a relatively low latency.

3.3 *Varying traffic load*

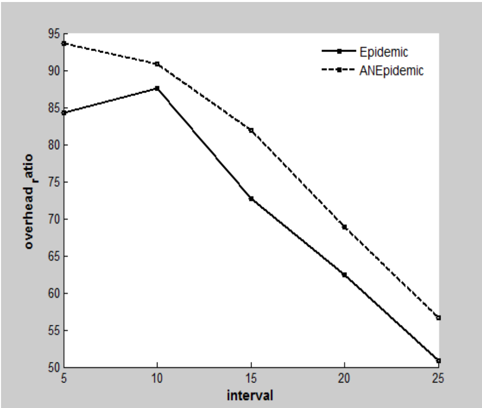
We decrease every message generation interval from 25 seconds to 5 seconds. Figure 3.a shows performance with varying message generation interval. Performance degrades in both protocols are with decreasing load.

The routing overhead is decreased with decreasing messages generation. ANEpidemic has lower overhead all the times due to the limitation in flooding by the angle and position control as shown in Figure 3.b.

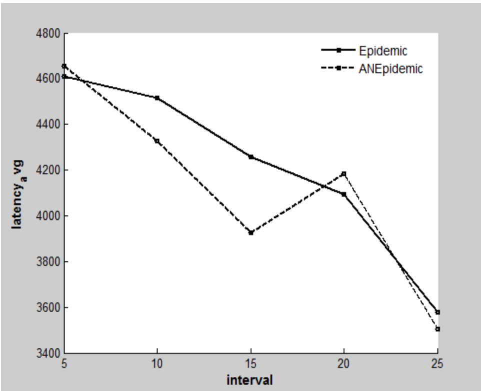
With very short message generation interval, the demands in network resources are higher. As shown in Figure 3c, the relative performance gain with our scheme is increased by virtue of utilizing position and angle information to avoid ineffective duplication of message.



(a) Delivery probability



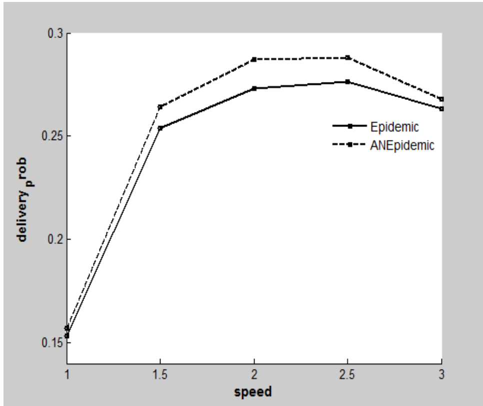
(b) Overhead ratio



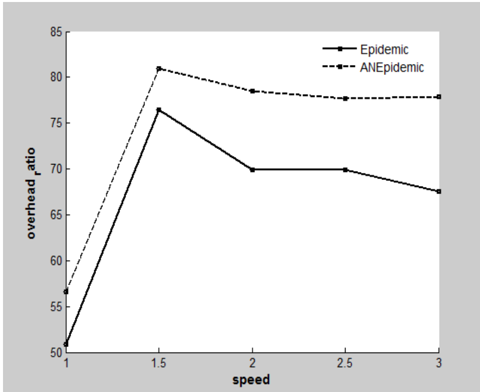
(c) Latency

Figure 3. The performance of varying traffic load.

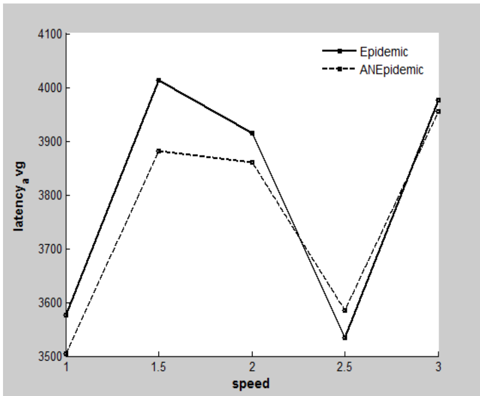
3.4 *Varying mobile speed*



(a) Delivery probability



(b) Overhead ratio



(c) Latency

Figure 4. Performance of varying mobile speed.

The maximal speed of node was increased from 1m/s to 3m/s. As shown in Figure 4(a), the increasing mobility improves the performance of both protocols due to the increasing chances of node meet probability.

As the mobility is increased, more nodes will encounter new node, and higher chance of duplicating message will encounter potential destination to some extent.

As shown in Figure 4(b), the routing cost is quite sensitive to the speed of nodes when it is increased. When the speed is low as shown in the figure, the amounts of forwarded messages of both algorithms are increased.

The probability of nodes which encounter new nodes is gradually increasing when the speed is increasing, which resulting in a large system overhead.

The speed which is increasing leads a significant delay variation. The proposed protocol has a lower delay in the lower moving speed. As shown in Figure 4(c), the difference in delay is not obvious in higher moving speed.

4 CONCLUSION

Epidemic algorithm improves the delivery rate by generating a large number of copies of the message. It is easy to implement and obtain high delivery rate. However, the copy and distribution of message without limitation lead to the decrease in network performance.

In this paper, the authors proposed a routing protocol that uses angle and position of neighbors to calculate the probability of encountering destination node.

The proposed ANEpidemic algorithm reduces the invalid replication of message by utilizing position and angle information of relay nodes. That is, the proposed protocol improves the delivery rate by limiting the number of copies of the message.

Simulation results show that the proposed algorithm has a better performance.

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REFERENCES

[1] Andrea Goldsmith. 2007. *Wireless Communications*, Oxford: Cambridge University Press.

[2] G. G. Joshi, C. B. Dietrich Jr., C. R. Anderson, W. G. Newhall, W. A. Davis, J. Isaacs & G. Barnett. 2005. Near-ground channel measurements over line-of-sight and forested paths, *IEEE Proc. Microw. Antennas Propag*., 152(6).

[3] Kovács Z. I. 2002. *Radio Channel Characterization for Private Mobile Radio Systems Mobile-to-Mobile Radio Link Investigations*, Ph.D. Dissertation, Denmark: Aalborg University.

[4] Z. Wang, E. K. Tameh & A. R. Nix. 2004. Statistical peer-to-peer channel models for outdoor urban environments at 2GHz and 5GHz, *IEEE 2004*.

[5] R.S. Akki. 1994. Statistical properties of mobile-to-mobile land communication channels. *IEEE Trans. Veh. Technol.*, 43(4): 826-831.

[6] K. Konstantinou, S. Kang & C. Tzaras. 2007. A measurement-based model for mobile-to-mobile UMTS links. Vehicular Technology Conference, VTC 2007-Spring. IEEE 65th.

[7] Vahdat, A. & Becker, D. 2000. Epidemic routing for partially connected ad hoc networks, Technical Report CS-2000 06, Duke University, April

[8] Lindgren, A., Doria, A. & Schelen, O. 2004. Probabilistic routing in intermittently connected networks, in *Proc. of the First International Workshop on Service Assurance with Partial and Intermittent Resources*.

[9] Burgess, J., Gallagher, B., Jensen, D. & Levine, B.N. 2006. MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks, in *Proc. of IEEE Infocom*..

[10] E.M. Belding-Royer. 2004. Routing approaches in mobile ad hoc networks, in: Mobile Ad Hoc Networking, IEEE/Wiley, pp: 275-300.

[11] Hany Samuel, Weihua Zhuang & Bruno Preiss Geneva. 2009. DTN based dominating set routing for MANET in Heterogeneous Wireless Networking, *Mobile Networks and Applications*. 14(2): 154-164.

[12] Xiaolan Zhang, Giovanni Neglia, Jim Kurose & Don Towsley. 2006. Performance modeling of epidemic routing, mobile and wireless communications systems, *Lecture Notes in Computer Science*, 3976: 827-839.

[13] Qingshan Wang & Zygmunt J. Haas. 2014. Performance analysis of epidemic routing for delay-tolerant networks. *Resource Management in Mobile Computing Environments (Modeling and Optimization in Science and Technologies)*, 3.

[14] Wu Y, Deng S & Huang H. 2014. Performance analysis of hop - limited epidemic routing in DTN with limited forwarding times. *International Journal of Communication Systems*.

[15] Wu Y, Deng S & Huang H. 2014. Performance analysis of hop-limited epidemic routing in DTN with limited forwarding times, *International Journal of Communication Systems*.