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Interest-based Epidemic Routing in Opportunistic Mobile Networks

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***Abstract*—Message delivery in opportunistic mobile networks is a challenging task since the network topology constantly changes and end-to-end paths can hardly be sustained. Epidemic routing forwards a copy message to each contacted node to achieve a high network delivery performance; this however easily burdens the network nodes with high traffic load, quickly depleting the node's resources, e.g. power and storage, and finally degrading the network delivery performance. This paper proposes an interest-based Epidemic that improves Epidemic to be a content-aware forwarding by taking message content, node interest, and node community into consideration. Using simulation, driven by real human contact datasets, we investigate the performance of the proposed algorithm compared with Epidemic (content-oblivious) and Direct Transmission (content-aware), in terms of total delivered messages, average convergence time, and total relayed messages. Simulation results show that Epidemic-Interest outperforms Direct Transmission in terms of total delivered message and average convergence time. Moreover, compared with Epidemic, it can reduces the transmission cost while keeping the total delivered messages as high as Epidemic's; however, it increases the convergence time beyond that of Epidemic.**

Keywords—content-aware forwarding, node interest, Epidemic routing.

I. Introduction

In recent years, opportunistic mobile networks (OMNs) have gained popularity in research and industry as natural evolution from mobile ad-hoc networks (MANETs). OMNs maintain the MANET's basic features of cost-efficiency and self-organization, as nodes still self-organize in order to build multi-hop message transfers without requiring any pre-existing infrastructure. However, they completely redesign the characteristics of networking protocols proposed in MANETs, enable them to deliver messages between nodes without the existing paths.

Epidemic routing [1] enables message delivery by adopting the concept of flooding. In this routing scheme, each node in the network maintains a set of information of the messages stored in its buffer. Whenever the node encounters its peer, they exchange the summary vector that indicates which entries in their local hash table are set and subsequently compare these vectors to determine which messages are missing. In the end, both the nodes have the same set of messages. Despite its benefit of a high delivery perfomance, Epidemic consumes a lot of the network resources; this issue is indeed critical in mobile networking where the nodes (or mobile devices) typically possess very limited resources, e.g. battery and storage. One approach to improve the Epidemic's poor performance in delivery cost is Priority Based Forwarding for Epidemic Routing [2]. This scheme utilize priority as a consideration on forwarding to reduce the number of messages in the network.

Traditional routing algorithms in OMNs [1][3][4] typically make forwarding decisions merely based on node contact information, e.g. contact frequency, duration and recency. On the other hand, study in [5][6] show that exploiting message content is also beneficial for message forwarding in social-aware networking such as OMNs. In this case, each node generates message content according to its own interest. The node interest and message content are furthermore considered when making forwarding decisions. In the literature, SCORP [7] and dLife [8] are examples of content-aware routing in OMNs.

In this paper, we introduce an interest-based Epidemic routing: we improve Epidemic by taking into account node interest and node community to select optimal relay nodes (or message carriers). An individual typically has one or more interests, and people with the same interest usually assemble together to talk about or share their common information. They usually contact more often and form a community. Conti and Kumar [9] identify two social network levels in OMNs: electronic and virtual social networks (as illustrated in figure 1). Mobile nodes (e.g. mobile phones, laptops, gadgets, and cars) form an electronic social graph when they are in proximity to make communications, and their spatio-temporal properties determine their social relationships. On the other hand, in a virtual social network humans have relations when they have a common interest (e.g. soccer or fishing) or social needs (e.g. colleagues or acquaintances).

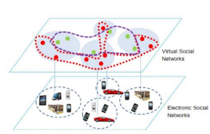

Fig. 1. Two social network layers in OMNs [9]

In order to make our algorithm easily understandable, in our model we assume that a person (or a node) has only one interest and generates a message with a content according to

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by Soelistijanto Bambang

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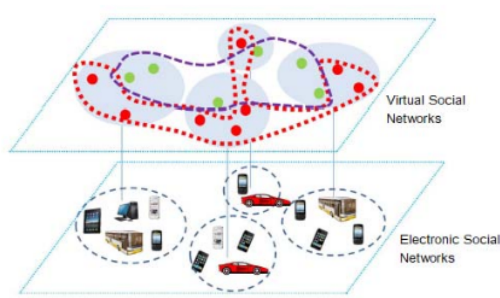

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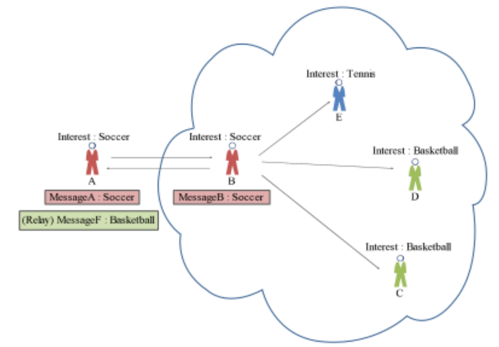
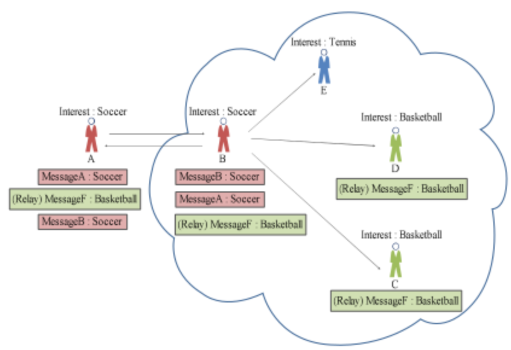


(a)



(b)

Fig. 2. Epidemic-Interest Routing

III. SIMULATION SETUP FOR EVALUATING EPIDEMIC-INTEREST ROUTING

We evaluate all the aferomentioned algorithms (Epidemic, Direct Transmission, and Epidemic-Interest) using the ONE Simulator, an event-driven simulator for mobile opportunistic network [14]. The main simulation parameters for this evaluation is described in Table 1. For the node mobility scenario, we use Haggle-3 Infocom-5 [15], and Reality MIT [16] datasets. Haggle-3 Infocom-5 trace captures the mobility of 41 bluetooth devices that are carried by attendees of IEEE Infocom Miami Conference in 2005 for 3 – 4 days. On the other hand, scenario in Reality MIT simulates the mobility of 100 student in MIT Media Lab and MIT Sloan Business over an academic year. In this study, we assume that each node only holding one interest. Moreover, in the simulation we define four interests, and subsequently these interests are distributed randomly and evenly for all the network nodes.

For performance analysis, we use several performance metrics as follows :

1) Total delivered messages: defines the number of messages successfully delivered to the destination.

2) Average convergence time: describes the mean of time that all the nodes in the network reaching the same information (with respect to the node interest).

3) Total Relayed Messages: quantifies the number of relay messages (message copies) created during the simulation times.

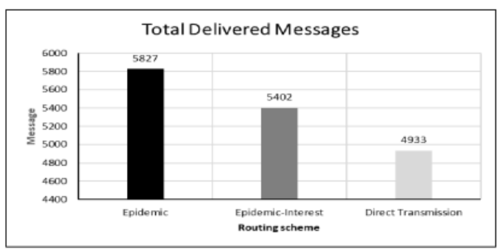
TABLE I. SIMULATION MAIN PARAMETERS

Simulation Parameters		
Mobility scenario	Haggle-3 Infocomm-5	Reality MIT
Number of nodes	100	41
TTl	720 minutes	20160 minutes
Familiar Threshold (F_{thres})	30, 90, and 180 minutes	2160, 6484, and 11008 minutes
K-value	3	5
Message size	10 KB	
Node buffer size	30 MB	
Message creation interval	290 – 310 second	

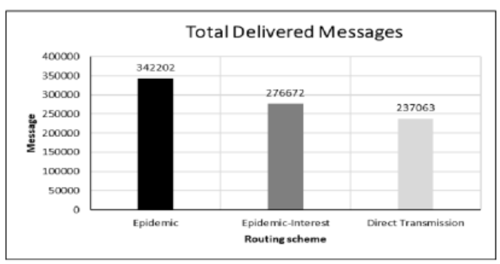
IV. SIMULATION RESULTS AND DISCUSSION

In this section, we evaluate our proposed algorithm, Interest-based Epidemic against Epidemic and Direct Transmission. We present the simulation results based on the three considered evaluation metrics in the Haggle-3 Infocomm 5 and Reality node mobility scenarios.

Figure 3a and 3b illustrate the total message delivered in Haggle-3 Infocom5 and Reality MIT traces, respectively. In this delivery performance, Epidemic clearly outperforms Direct-Transmission and Epidemic-Interest in both node mobility scenarios. In Epidemic, in every node contact a current node forwards its all messages to the peers regardless the peer interests, increasing the probability of messages received by the destination. In contrast, Direct-Transmission has the lowest total delivered messages due to its strict preference on only exchanging messages with the peers with the interest similar with the message content. Meanwhile, Epidemic-Interest allows a peer to be a message carrier for its community, leading to the increase of total message delivered beyond that of Direct-Transmission.



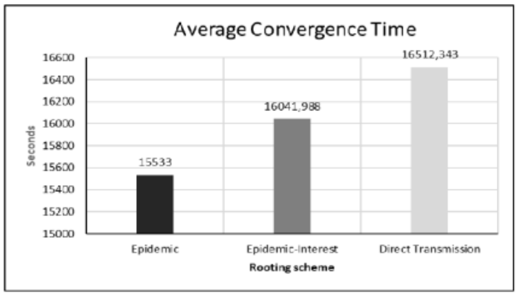
(a) Haggle-3 Infocom5



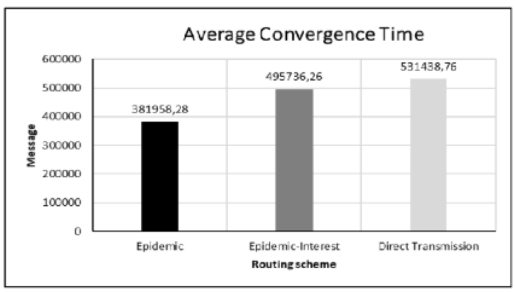
(b) Reality MIT

Fig. 3. Total delivered messages performance of different forwarding strategies

Figure 4 shows the average convergence time to reflect the delay transmission performance of the algorithms in the network. In the Direct-Transmission scheme, nodes do not hand over the (copies) messages to the contacted nodes unless the peers have the same interest with the given nodes'. Consequently, the algorithm has the highest delay transmission compared to those of Epidemic and Epidemic-Interest in both mobility scenarios. On the other hand, Epidemic-Interest can outperform Direct-Transmission in terms of delay transmission, but it has a slower convergence time than that of Epidemic. In Epidemic, a high fraction of the network nodes carry the copies of a message, resulting in the lowest transmission delay; in contrast, Epidemic-Interest is more selective to forward the message copies to the encountered nodes, increasing the delivery latency above Epidemic's.



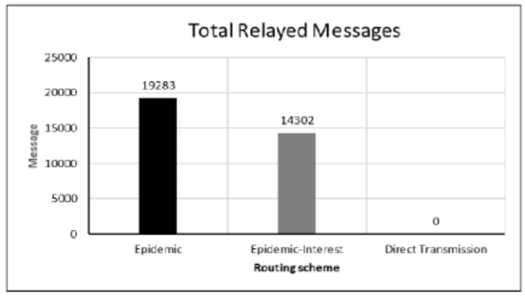
(a) Haggle-3 Infocom5



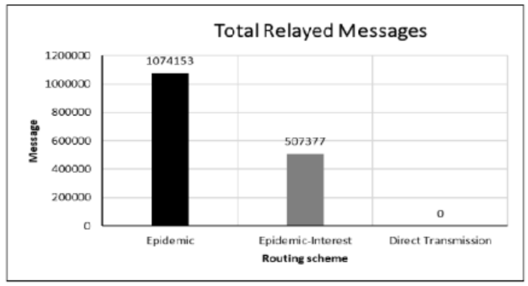
(b) Reality MIT

Fig. 4. Convergence time performance of diferent forwarding strategies

Finally, we depict the delivery cost performance measured in total message copies created during the simulation in figure 5. We notice that Epidemic–Interest has a lower total relayed messages than that of Epidemic in both node mobility scenarios. This Epidemic-Interest higher delivery cost performance however is at the expense of a lower total message delivered and a higher delivery latency compared with those of Epidemic. Whereas, in Direct-Transmission the delivery cost is zero because the algorithm forwards the messages directly to the peers with the same interest with the current node, meaning that Epidemic-Interest does not produce relay messages during node contacts throughout the simulation.



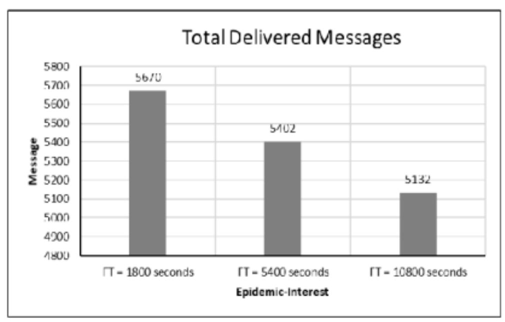
(a) Haggle-3 Infocom5



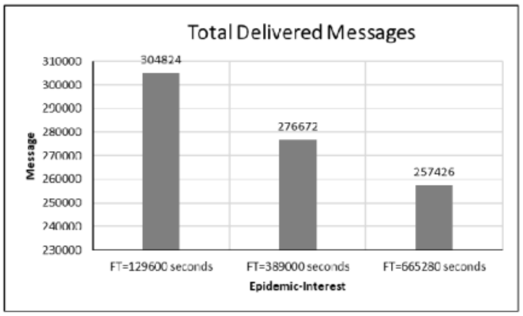
(b) Reality MIT

Fig. 5. Relayed Messages in Haggle-3 Infocom5 and Reality MIT tracea

In addition to the Epidemic-Interest performance evaluation, we now examine the effect of different familiar thresholds on the algorithm's delivery performance. Lower F_{thres} results in many more peer nodes are included in the current node's community, and on contrary higher F_{thres} means that longer contact duration times are considered in the node community detections.



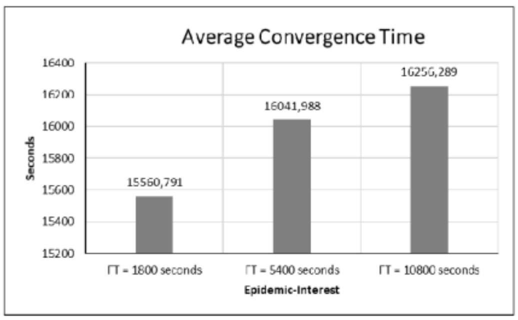
(a) Haggle-3 Infocom5



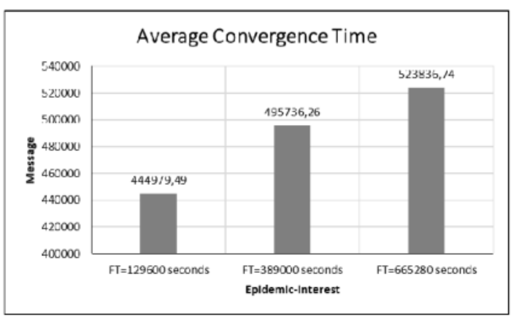
(b) Reality MIT

Fig. 6. Delivered Messages with different familiar thresholds

Figure 6 shows the implication of using different familiar thresholds on the total delivered messages. In both Haggle-3 infocom5 and Reality traces, low familiar threshold created community with a lot of member. Clearly, this gives a higher chances for the node to hand over its copy of messages to its peer, leading to the increase of total delivered messages.



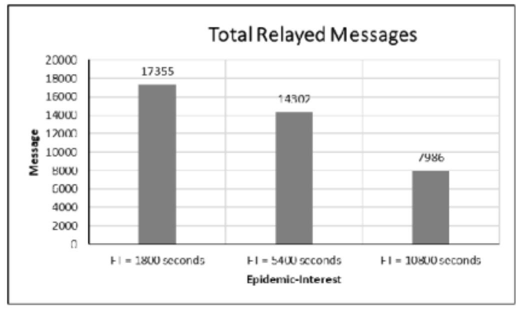
(a) Haggle-3 Infocom5



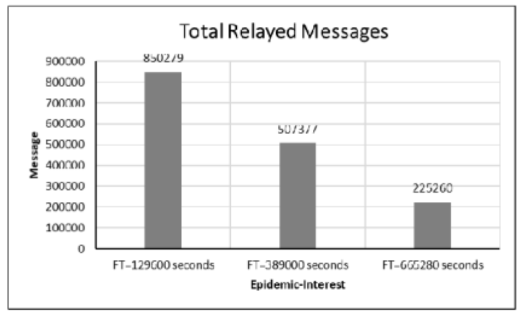
(b) Reality MIT

Fig. 7. Convergence time with different familiar thresholds

Next, the average convergence time (depicted in figure 7) is measured to observe the delay transmission of Epidemic-Interest with different familiar thresholds. As the familiar threshold increases, the community member are getting smalller, decreasing the chances of the peer to be selected as a relay node for its community member, resulting in a longer time to distribute the messages throughout the network. Consequently, the average convergence time is higher. On the other hand, as shown in figure 8 the algorithm with a high familiar threshold produces a total relay messages significanty lower than that of low familiar threshold in both human contact datasets.



(a) Haggle-3 Infocom5



(b) Reality MIT

Fig. 8. Relayed messages with different familiar thresholds

In summary, Epidemic-Interest with a low familiar threshold produces a short convergence time and a high total delivered messages, however this creates a high delivery cost. On the opposite, although Epidemic-Interest with a high familiar threshold produces a long convergence time and a lower total message delivered, it is able to decrease traffic in the network, measured in total relayed messages.

V. CONCLUSION

In this paper, we introduce Epidemic-Interest that considers node interest and message content as the forwarding criteria in OMNs. We evaluate the proposed algorithm against Epidemic (content-oblivious) and Direct-Transmission (content-aware). Our study shows that in terms of average convergence time, total relayed messages, and total delivered messages, Epidemic-Interest outperforms Direct-Transmission as it considers not only peers' interest but also the interest of nodes in the peers' communities. Meanwhile, Epidemic-Interest has slower convergence time than that of Epidemic. However, Epidemic-Interest can limit the number of (copies) messages in the network than Epidemic's; thus, Epidemic-Interest can reduces the delivery cost of Epidemic.

Finally, we evaluate the impact of choice of familiar threshold in the Epidemic-Interest's delivery performance. As stated, familiar thresholds affect on the size of established communities. Lower familiar thresholds produce communites with a large number of nodes; this implies that a high probability of nodes selected as relay nodes for their communities, leading to a lower delivery latency of the messages spreading in the network and a high total delivered messages. Despite its benefit, the lower familiar thresholds increases delivery cost, measured in total relayed messages during the simulation. On the other hand, higher familiar thresholds produce a long convergence time, but it can reduce the network traffic as it generates a lower total relayed messages.

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