2019 7th International Conference on Information and Communication Technology (ICoICT)
July 24-26, 2019
Kuala Lumpur, Malaysia

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It is our great pleasure to announce that the 7th International Conference on Information and Communication Technology (ICoICT 2019) will be held in Kuala Lumpur, Malaysia on July 24 - 26, 2019. Kuala Lumpur is the capital city of Malaysia as well as the largest city in the country. It is the cultural and economic hub of Malaysia with a wide range of recognized landmarks including the iconic twin skyscrapers of Petronas TwinTowers, Menara KL and Istana Negara.

ICoICT 2019 is jointly organized by Multimedia University Malaysia and Telkom University Indonesia. The conference offers a good opportunity to enhance international academic exchange on ICT related topics and to provide a platform for researchers to discuss new problems and solutions. ICoICT 2019 will feature traditional paper presentations, poster presentations, tutorials, demos, as well as keynote speech by renowned educational experts and industrials.

Papers from the previous ICoICT 2013, 2014, 2015, 2016, 2017 and 2018 have been included in IEEE Xplore:

ICoICT 2013 : http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6569393
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2019 7th International Conference on Information and Communication Technology (ICoICT) Important Dates:

| | |
|---|---|
| Call for Paper | August 1, 2018 |
| Paper Submission Deadline | March 15, 2019 |
| Extended Paper Submission Deadline | March 31, 2019 |
| Notification of Papes Acceptance | April 30, 2019 |
| Submission of Camera Ready Papers | May 15, 2019 |
| Author Registration Deadline | May 31, 2019 |
| Conference Date | July 24-26, 2019 |

The previous ICoICT conferences have successfully served a forum to bring together a diverse group of people from academics and industrial to share and present the latest issues and recent developments in the area of ICT. ICoICT 2019 is technically sponsored by IEEE Systems, Man, and Cybernetics (SMC) Malaysia. All accepted papers in ICoICT 2019 will be published in the conference proceedings and will be submitted for publication.

We look forward to seeing you in Kuala Lumpur Malaysia!

2019 7th International Conference on Information and Communication Technology (ICoICT)


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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).

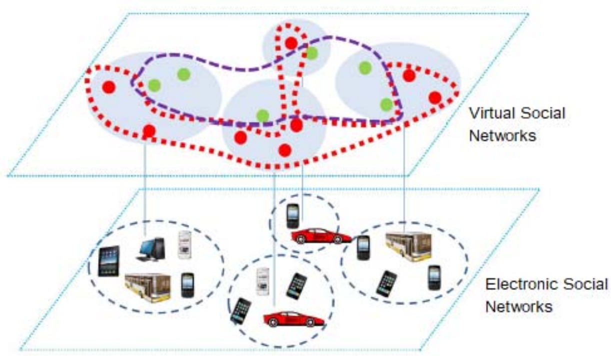



Fig. 1. Two social network layers in OMNs [9]

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 his/her own interest. The message subsequently is broadcasted to nodes whose interests are the same with the message content. In Epidemic [1], when node contacts occur the copy of the message will be sent to all the peers, regardless the peers' interest (we refer this as a *content-oblivious* forwarding). When Epidemic is able to deliver messages with a high delivery performance (i.e. a high delivery ratio and/or a low delay), it however produces an abundance of traffic in the network, quickly depleting the nodes' resources, e.g. power and buffer, and eventually degrading the nework delivery performance. In consequence, we improve Epidemic to be a *content-aware* forwarding: in this scheme, the copy message will only be forwarded to the peers whose interest is related with the message content (hereafter, we name this *Epidemic-Interest* routing). In addition, to reduce the large delivery latency of this protocol we then add a community-aware strategy in the forwarding decisions as follows: a node with a different interest with the message content may be chosen as a carrier of the message if the node belongs to the community whose members posses interests that are inline with the message content. Moreover, as in [9], we define node community in the context of electronic social networks, and consequently a node community detection algorithm [10] is performed based on node contact statistics. Finally, to benchmark our proposed algorithm we refer to both Epidemic and a simple content-aware routing algorithm where in this method the copy message directly forwards to nodes whose interests are the same with the message content, i.e. no need node relay selections in the forwarding strategy (hereafter, we call it *Direct-Transmission* routing).

The rest of the paper is organized as follows. In Section II, we describe the proposed algorithm of Epidemic-Interest routing. Simulation setup and performance metrics for evaluating the protocol are provided in Section III. Section IV discuss the simulation results. Finally, Section V concludes the paper.

## II. Epidemic-Interest Routing Algorithm

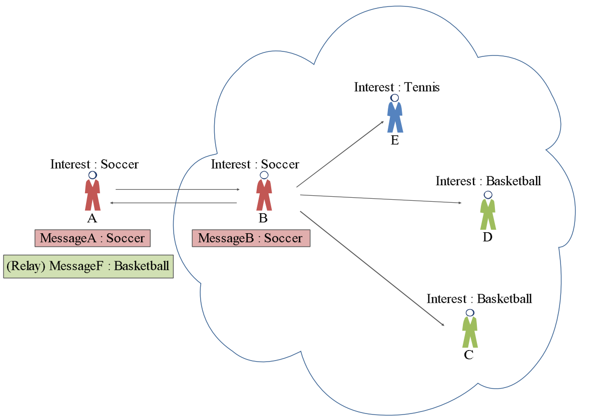
This section describes our content-aware routing Epidemic-Interest, which takes into account message content, node interest, and node community to make forwarding decisions. We illustrate the algorithm in figure 2. Initially, node A with interest in soccer carries two messages, comprising its own message with a content of soccer and a relay message containing information of basketball (figure 2a). During its mobility, node A meets node B having an interest in soccer as well. Similar to Direct-Transmission scheme, Epidemic-Interest algorithm of node A certainly forwards its own message of soccer to B, since this message content agrees with the node B's interest. Subsequently, for the node A's relay message of basketball, unlike Direct-Transmission that prevents node A transmitting the message to node B since the node B' interest is unmatched with the message content, Epidemic-Interest however allows node A to select node B as a message carrier if the latter has one or more friends inside its community who have an interest agreeing with the message content. As shown in figure 2b, since node B has two friends having an interest in basketball in its community (node C and D), then node B is finally selected as an message carrier for them.

From above discussion, it is obvious that the effectiveness of Epidemic-Interest relies on the node communiy detection strategy. Community (or social clique) is inspired from gregarious properties of society, where members of a community meet more often than others from outside communities. In the literature, several community detection schemes [11][12] have been proposed to design good strategies for message delivery in OMNs. However, most of them are centralized and focus on analysis of offline human mobility traces. In this study, we use the *K*-clique distributed community detection algorithm proposed by Hui *et. al.* [13]. For a graph $G = (V, E)$, a clique is a complete subset of graph $G$ in a such way that there are adjacent vertices. *K*-clique defines the subset of graph $G$ whose number of adjacent vertices equal to *k*. *K*-clique community refer to a community of *k*-clique subgraph which are reachable from one clique to another. The distributed computation in [13] initially defines a familiar set of node A ($F_A$), which is a set of direct contact neighbours of node A. When node A encounters its peer node B, node A keeps track of their contact duration time. When the total contact duration time exceeds a certain threshold (called familiar threshold, $F_{\text{thres}}$) then node B will be added to node A's familiar set. Finally, a community set of node A ($C_A$) is set up comprising of nodes in set $F_A$ and also all nodes which are selected by the *k*-clique detection scheme.

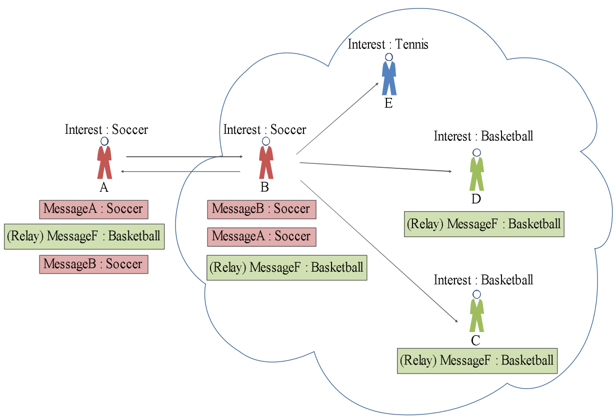
Finally, we show the forwarding algorithm of Epidemic-Interest of node A in Algorithm 1. Whenever node A, $N_A$, with interest $I_A$ encounters node B, $N_B$, with interest $I_B$, they initially exchange summary vectors (SVs), informing to the peer about the messages kept in the current node's buffer. This typical Epidemic's step is then followed by both nodes exchange their community sets ($N_A$ receives $C_B$ and vice versa). $N_A$ next examines each message M in the buffer: if M does not exist in $N_B$'s buffer and M contains information ($I_M$) that is related with the interest of node B ($I_M = I_B$), then a copy of M is immediately sent to $N_B$. Otherwise, if the community set of node B, $C_B$, contains nodes with an interest matches with $I_M$, then $N_B$ is selected as a carrier of message M and $N_A$ forward the M copy to $N_B$; or else, $N_A$ keeps M for next node contacts.

Algorithm 1. Epidemic-Interest forwarding strategy ($N_A$)

```
While NA is in contact with NB do
  /* exchange summary vectors */
    send    SVA
    receive SVB
  /* exchange community sets */
    send    CA
    receive CB
  /* forwarding decision on a message M */
    while ∃ M ϵ buffer (A) do
      if IM = IB
        then forward (copy of) M
          else
            // examine interest of node N of NB's community
            while ∃ N ϵ CB do
              if IM = IN
                then forward (copy of) M
                  else keep M
              end if
      end if
```




(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.

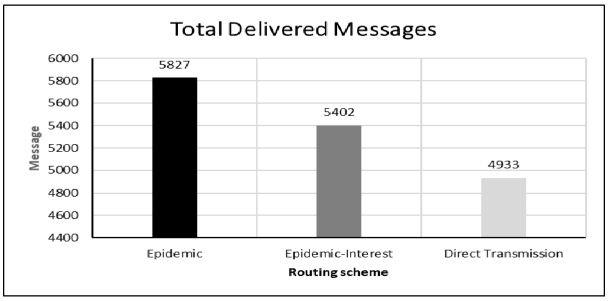
TABLE I. Simulation Main Parameters

| 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 | |

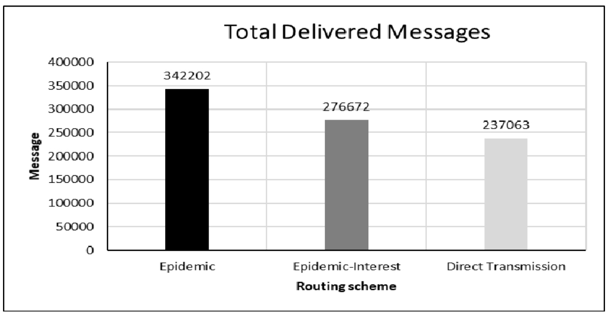
## IV. Simulation Results and Discussion

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.



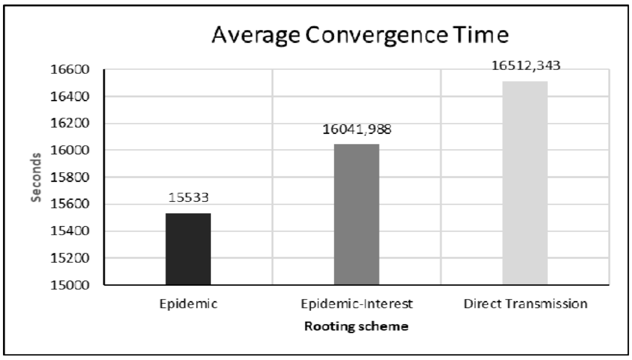

(a) Haggle-3 Infocom5



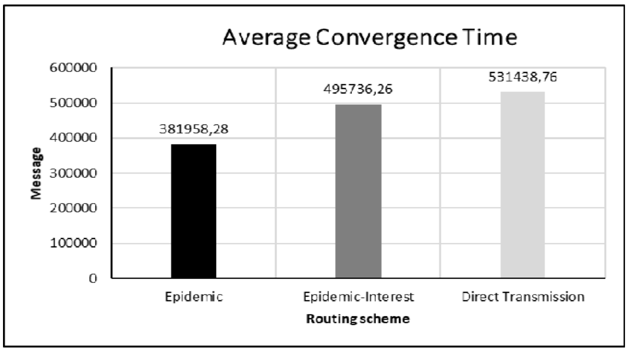

(b) Reality MIT

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.



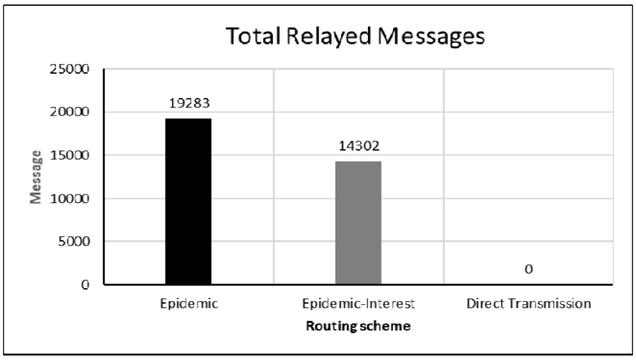

(a) Haggle-3 Infocom5



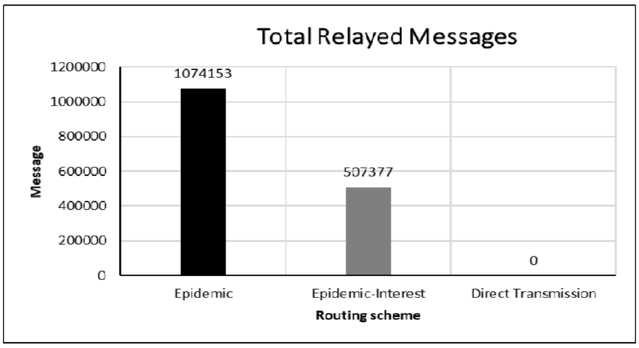

(b) Reality MIT

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.



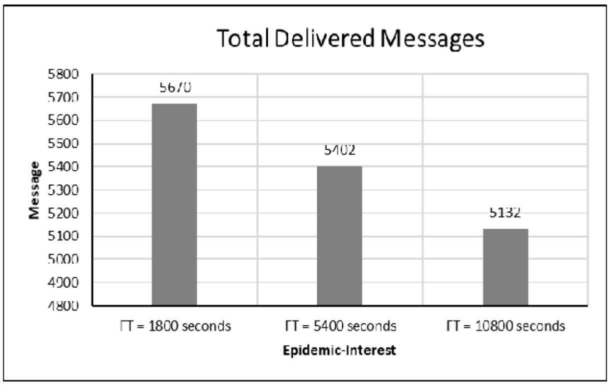

(a) Haggle-3 Infocom5



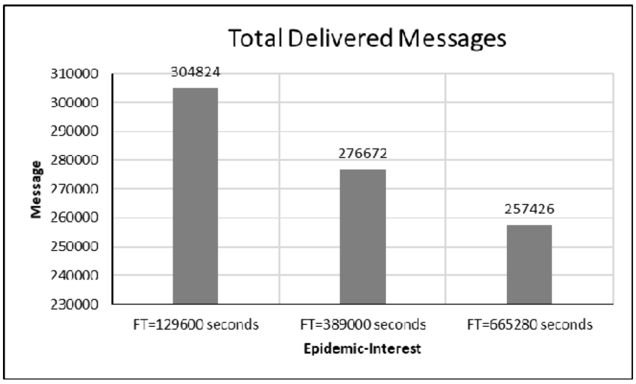

(b) Reality MIT

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.



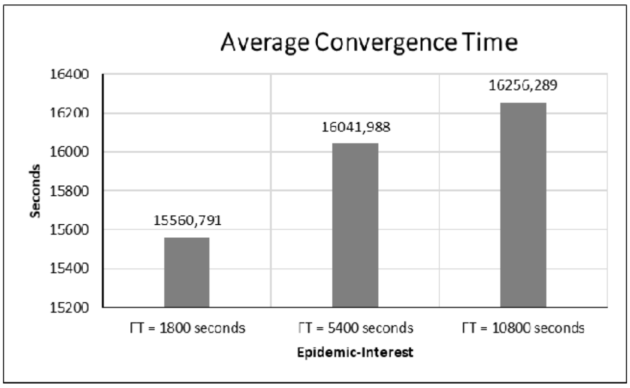

(a) Haggle-3 Infocom5



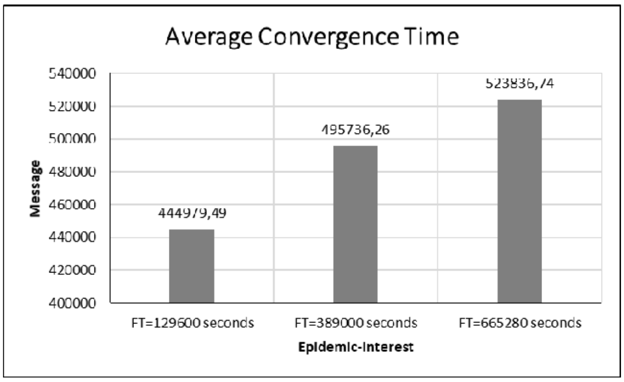

(b) Reality MIT

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.



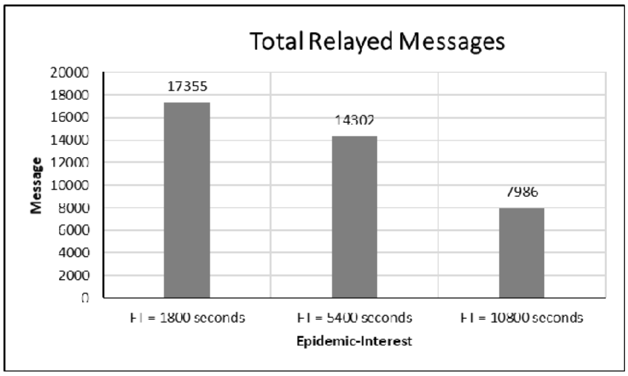

(a) Haggle-3 Infocom5



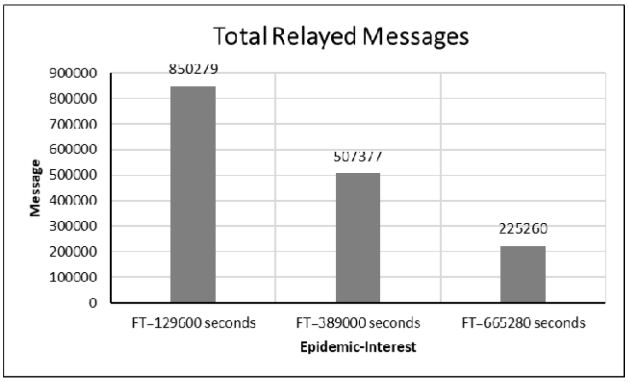

(b) Reality MIT

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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