Computer Communications 65 (2015) 10–26

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

Social based throwbox placement schemes for large-scale mobile social delay tolerant networks

Ying Zhu [a], Chao Zhang [a], Xufei Mao [b], Yu Wang [a,*]

[a] Department of Computer Science, University of North Carolina at Charlotte, Charlotte, NC 28223, USA
[b] School of Software, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Article history:
Available online 14 March 2015

Keywords:
Social based approach
Throwbox-assisted
Throwbox placement
Mobile social networks
Delay tolerant networks

ABSTRACT

Mobile phone sensing is a new paradigm which takes advantage of smart phones to collect and analyze data at large scale but with a low cost. Supporting pervasive communications among mobile devices in such a large-scale mobile social network becomes a key challenge for this new mobile sensing system. One possible solution is allowing packet delivery among mobile devices via opportunistic communications during intermittent contacts. However, the lack of rich contact opportunities still causes poor delivery ratio and long delay, especially for large-scale networks. Deployment of additional stationary throwboxes can create a greater number of contact opportunities, thus improve the performance of routing. However, the locations of deployed throwboxes are critical to such improvement. In this paper, we investigate where to deploy throwboxes in a large-scale throwbox-assisted mobile social DTN. By leveraging the social properties discovered from real-life tracing data, we propose a set of social-based throwbox placement algorithms which smartly pick the location of each throwbox. Extensive simulations are conducted with a real-life wireless tracing dataset and a wide range of existing DTN routing methods. The results confirm the efficiency of the proposed methods.

1. Introduction

With the increasing popularity of smart phones equipped with a set of versatile sensors, it becomes possible to perform ubiquitous sensing via a mobile sensing network formed by a large amount of mobile phones [1]. Such a new paradigm of mobile sensing, where each mobile device is held by an individual, can provide abundant data about individuals, human society and environments. Some examples of mobile sensing applications include traffic information [2,3], environmental monitoring [4,5], human mobility modeling [6,7], important place extraction [8,9], urban sensing and planning [10,11], parking information [12], sociology [13–15], ecology and epidemiology [16].

One of the challenges for large-scale mobile sensing or mobile networking is how to efficiently transfer data among mobile devices. For smart phones, we are currently facing the challenge of mobile data explosion. Based on the most recent Cisco's report [17], mobile data traffic grew 70% in 2012 and reached 885 petabytes per month at the end of 2012, which was nearly 12 times the size of the entire Internet in 2000 (75 petabytes per month). Cisco also forecasts that mobile data traffic will surpass 10 exabytes per month in 2017. In addition, the recent advance in machine-to-machine (M2M) communications may potentially add billions of devices into mobile Internet. By the end of 2013, the number of mobile-connected devices will exceed the number of people on earth [17]. However, the current cellular networks do not have enough capacity to support all of the fast-growing mobile data from these mobile devices and the new applications of mobile sensing [18–20]. "*The technology evolution of radio access networks is limited by the laws of physics, and significant growth in radio frequency efficiency can no longer be expected. Long-Term Evolution (LTE) radio access is reaching the limits of Shannon's law, the spectrum available for mobile data applications is limited*", regarding to [18]. Therefore, looking for new ways to increase the overall capacity and satisfy fast-growing mobile data is emerging as a new topic for cellular industry.

To avoid overloading the cellular networks, one of the possible offloading solutions is using opportunistic communications to deliver data packets [19–21] via a mobile Delay Tolerant Network (DTN). The major advantage of this solution is low cost and easy to deploy even in a large-scale network. However, intermittent connectivity in DTNs results in the lack of instantaneous end-to-end paths, large transmission delay and unstable network topology. To overcome these challenges, many DTN routing algorithms [22–33] have been proposed by relying on intermittent contacts

* Corresponding author.
E-mail address: yu.wang@uncc.edu (Y. Wang).

http://dx.doi.org/10.1016/j.comcom.2015.02.008
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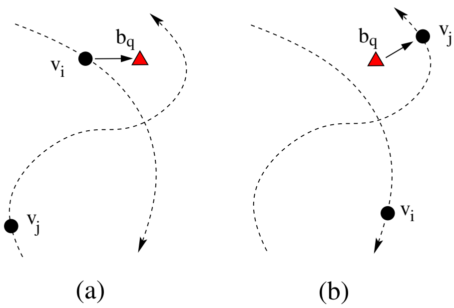

Fig. 1. Illustration of throwbox-assisted mobile social DTNs: (a) when a mobile node v_i passes by a throwbox b_q, it can left a copy of the message to b_q; (b) later, throwbox b_q can then forward the message to another passing by mobile node v_j.

between mobile nodes to deliver packets. However, the lack of rich contact opportunities in many DTNs (especially those with sparse deployments) still causes poor delivery ratio and long delay of DTN routing [34,35]. For example, as shown in [35], the delivery ratios of existing DTN routings in a large-scale mobile social network are only around 30–40%. Therefore, there are still spaces to further improve the deliver ratio of opportunistic routing in large-scale mobile networks.

One way to improve mobile DTN performance is to deploy additional stationary nodes, called *ThrowBoxes* (TBs), to create a greater number of contact opportunities [34,36,38–41]. Throwboxes are usually small, battery-powered, and inexpensive devices equipped with wireless interfaces and storage. They are stationary and can relay data between mobile nodes in a *store-and-forward* way. As

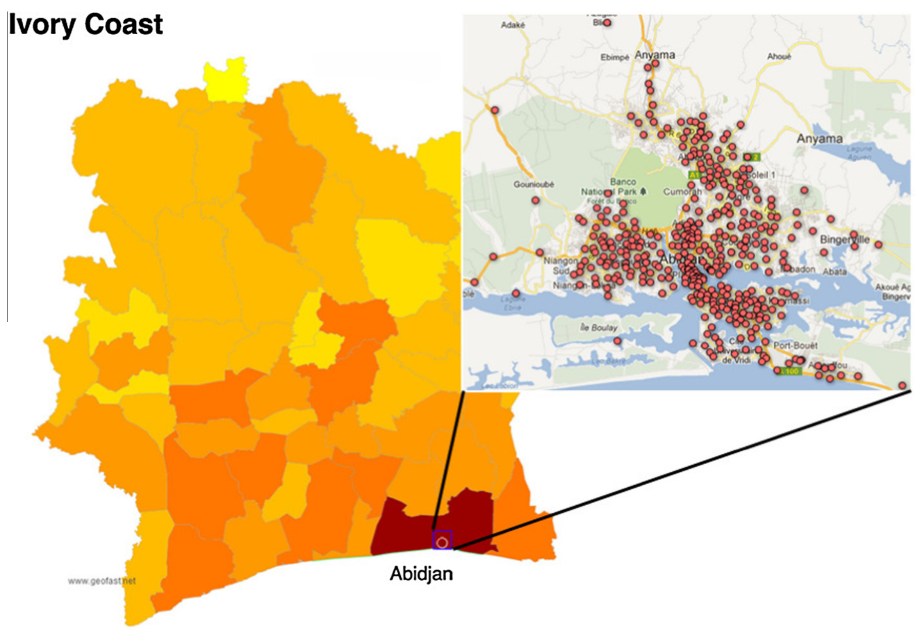

Fig. 2. Visualization of D4D dataset: the traffic distribution among all regions are shown in color where darker color indicates heavier traffic loads; the small blue rectangle around Abidjan shows the limited region with high traffic we select for our simulations; and a zoomed view of the detailed tower distribution within the selected region is also provided. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

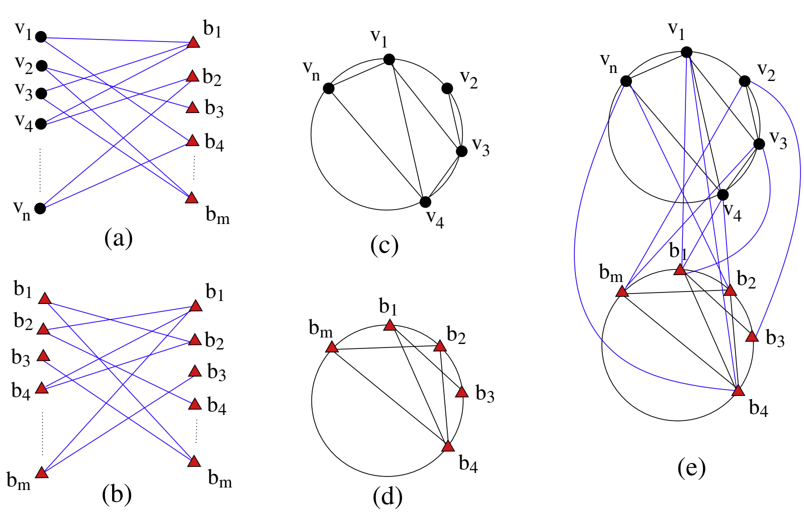

Fig. 3. Illustration of social graphs in mobile social DTNs: (a) the *user-location* bipartite graph G_{ub} shows every user's top 2 locations; (b) the *location–location* bipartite graph G_{bb} shows every location's top 2 locations; here we assume that the total visiting frequencies or durations of b_2 and b_m to b_1 are larger than that of b_4. (c) the social graph among users G_u; (d) the social graph among locations G_b; (e) the whole social graph among users and locations G. In all examples, we use top 2 locations instead of top 10 for simple illustration.