Exploring Shopping Mall Environment for Ubiquitous Computing

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***Abstract*—Mobile ad-hoc sensor networks are very beneficial in many ubiquitous computing applications and situations such as military operations, construction sites, stadiums, convention centers, emergency services, inhospitable physical environments, music festivals, automobile race tracks, trade fair and shopping mall. Validation of mobile ad-hoc and delay tolerant network protocols for such environments is problematic. It relies almost exclusively on simulations which make use of movement models. Furthermore, each scenario is characterized by its own distinctive mobility model. It is very difficult collecting real mobility data and in the recent years many efforts have been made aiming to build realistic mobility models. In order to conduct informed and realistic design of forwarding policies and algorithms for mobile ad-hoc sensor networks, it is important to gather real human mobility data. In this paper we study human mobility in a shopping mall environment. From this we make recommendations for the design of opportunistic forwarding algorithms for such environments.**

***Index Terms*—Measurement, Ubicomp, Human Mobility.**

I. Introduction

Pervasive computing has entered the backpack, purse, and coat pocket in the form of mobile phones. In this context mobility plays a key role in the forwarding of data as it is mobility which gives rise to local connection opportunities when access to network infrastructure is not available. For this reason studying human mobility in different environments for extended period of time is essential. It is likely that successful forwarding algorithms will be based on locally learned information. It can turn out to be even more resource starved than a MANET where one eschews proactive routing. Thus we need to measure what we can statistically learn locally and then use those measurements to drive the development and evaluation of appropriate forwarding algorithms. Recently, several significant efforts have been made to collect data reflecting node movements in real large-scale mobile ad hoc environments [1]-[4]. However, these traces are from specific scenarios and their validity is difficult to generalize. For example, in order to evaluate forwarding algorithms, accurate data is needed on the intermittency of connections.

We have been considering applications in shopping mall environments and decided to collect real-world Bluetooth contact data for shopkeepers of a shopping mall over six days. This will allow us to conduct informed design of forwarding policies and algorithms for such scenarios, and determine the effects of users' mobility patterns on the prevalence of networking opportunities. In this paper we summarize our experimental results. We argue that these have implications for the design of forwarding algorithms for ubiquitous computing applications.

II. Experimental Analysis

Our experiment aimed to collect data on the frequency and duration of contact between devices carried by people (inter-contact time and contact duration). Gathering such a data set presents many practical issues: dealing with deployment of mobile devices to a certain number of shopkeepers, the battery life of the devices, and minimizing the inconvenience of carrying the devices so that they are willing to do so at all the times. We set up our own experiments making use of smart phones running symbianOS and using Bluetooth technology.

We carried out neighbor discovery approximately every 120 seconds. The Bluetooth 1.1 specification states that an inquiry process for neighbor discovery should last about ten seconds. The experiment involved twenty-five mobile devices, seventeen of which were carried by shopkeepers and shop assistants and eight of which were static used as fixed points.

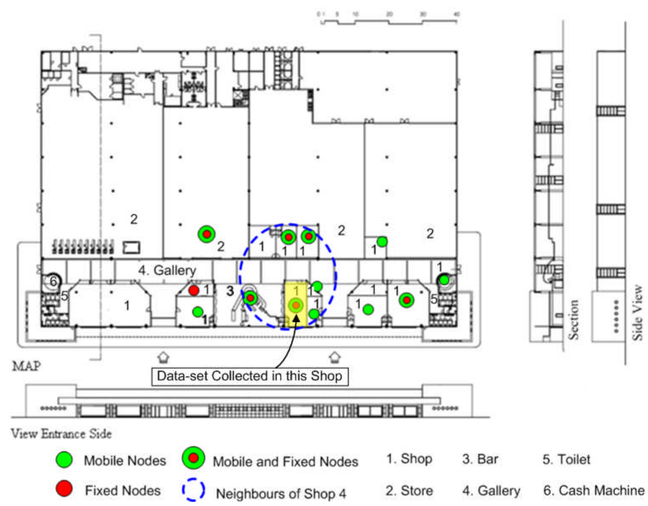

Figure 1: Map of the shopping mall with 13 shops, 18 mobile devices and 7 fixed devices involved in the experiment

For six days these devices were given to the participants at around the same time, 9:15 am, and collected at 8:45pm. They carried the devices all day long during the working day (from 09:00am to 01:00pm and from 03:00pm to 09:00pm).

We analyze connection opportunities in terms of contacts by means of inter-contact time, related to the frequency with which packets can be transferred between networked devices. Our results are influenced by the duration and granularity of the experiments. Indeed, short event lengths are affected by the granularity of measurement (around 134 seconds). Similarly, events lasting longer than the experiment cannot be observed. In Figure 2 we plot six days inter-contact time distributions of two smart phones, one working in a fix point and one mobile, both assigned to the shop indicated in Figure 1. We identify inter-contact time of four groups; in order, by considering exclusively customers, all the contacts, all the 25 smart phones (i.e. other shops and shopkeepers) and only neighboring smart phones (those in the dashed circle in Fig. 1) in the last one. The diagrams also show that the fixed and mobile device have mostly the same distribution. This could be explained by shopkeepers being mainly located during the working time in the shop where they work and thus having the same contacts in sight. All of them exhibit a strong heavy tail property which can be observed as an approximate power law for the time scale [2min:1hour]. Notice, the neighboring shopkeepers' distribution (in Figure 2) expresses a power law with coefficient 1.30. This is relevant since using multiple intermediate relays is sufficient for stateless forwarding algorithms to converge [1]. After about one hour all of the graphs tend to keep the same probability till the end of the working day. The shape of the distributions in Figure 2 tells us that inter-contact times are either roughly smaller than one hour or bigger than twelve. This is most evident in the neighboring shopkeepers' graph (4) where it is flat from around 30 minutes to 12 hours. This suggests that shopkeepers, sellers and shop assistants in the shopping mall are most of the time in contact with each others allowing a MANET-like connectivity. Above one hour most of the inter-contact times are bigger than twelve hours (time between two working days). This suggests that customers commonly spend up to about an hour in the shopping centre but at least somes come back the next day. This is backed up by Figure 3 (contact duration): contact durations for customers are smaller than 1 hour. The order of the distributions in Fig. 3 is inversed with respect to the one in Fig. 2. Neighboring shopkeepers exhibit higher contact durations and shorter inter-contact time, suggesting they could form part of a more reliable network.

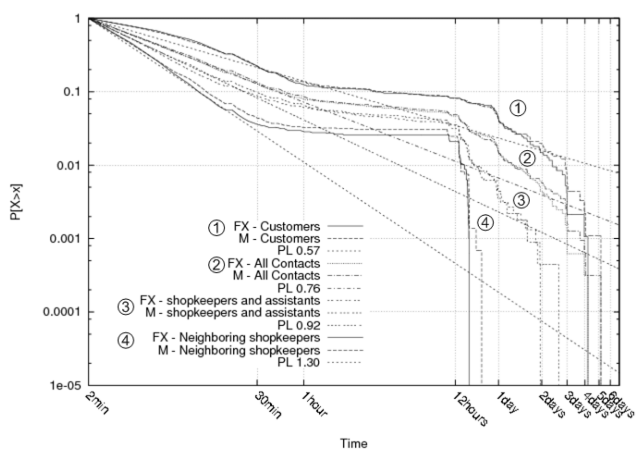

Figure 2: Tail Distribution Functions of the Inter-Contact Time along six days for the customers, all the contacts, all the 25 smart phones, and the neighboring smart phone

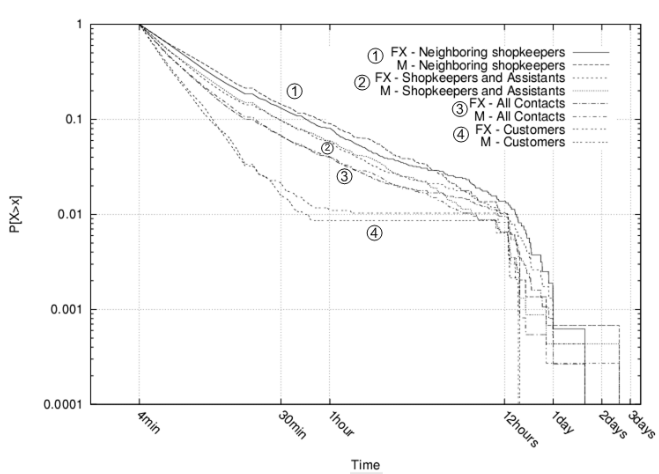

Figure 3: Tail Distribution Functions of the Contact Duration along six days for the neighboring smart phone, all the 25 smart phones, all the contacts, and the customers

III. Conclusion

We have presented real-world measurement results from the mobility of people in a shopping mall environment. These results are quite different from previous studies in workplace, university campus and conference scenarios where power law coefficients approximate the inter-contact time distributions for longer periods of time. In our experiments we have identified groups of people which express higher power law coefficients but only for short time periods. The neighboring shopkeepers' distribution (4) revealing a PL with coefficient located between 1 and 2 [1]. Our results also show that inter-contact time between shopkeepers in a working day is typically smaller than 30 minutes which lets us assume shopkeepers will be more reliable for forwarding data. The obtained distributions suggest that forwarding to neighboring shopkeepers and assistants increases significantly the likelihood of timely contact. The identification of such groups of people can help greatly in forwarding data.

In future work we intend to create mobility models which will accurately represent the observed human mobility patterns, and design and evaluate forwarding algorithms for different ubiquitous applications in this type of setting.

References

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