Detail Characterization of Paths in Pocket Switched Networks

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ABSTRACT
Pocket Switched Networking (PSN) is a new communication paradigm between mobile devices. It takes advantage of every local communication opportunity, and the physical mobility of the devices, in order to transport data.

In this work, we followed an experimental approach, using real measurement of human mobility patter, to study the characteristics of forwarding paths found in a PSN environment. We describe for the first time the waiting time statistics of delay-optimal paths, and draw some of their consequences on the analysis of a forwarding algorithm.

Keywords
Pocket Switched Network, Network measurement, human mobility, wireless Networking.

1. INTRODUCTION
Delay Tolerant Networks (DTN) explores networking in the presence wireless devices that are occasionally connected. DTNs present frequent partitions, which make the use of contemporaneous end-to-end paths impractical.

The goal of PSN is to use a huge amount of devices carried by humans and exploit their inherent mobility to find more and more communication opportunities between them. In this communication paradigm, one may use local connectivity between two or more devices, global connectivity provided by an infrastructure, as well as physical mobility of the devices to carry data to an appropriate endpoint.

Understanding human mobility to enable faster data delivery represents an important research issue for PSN. Several networking research groups have already studied human mobility. Many of these works aimed at analysing and informing the design of infrastructure-based networks; some of them use data gathered on large wireless 802.11 networks such as UCSD [5] and Dartmouth [6]. Other works [3, 4] have directly considered networks without a fixed infrastructure; most of them rely on simple mobility models like the Random Waypoint, or one of its variants. More recently, performance of opportunistic forwarding in PSN was studied on the basis of human mobility measurement [1, 2]. Simple forwarding techniques have already been considered and evaluated in these works, but despite some promising facts that we remind below, these algorithms appear to be too costly to be used in a real deployment.

CoNext'06, December 4–7, 2006, Lisbon-Portugal.

The main contribution of this work is to characterize further the properties of paths used in a Pocket Switched Networks, to optimize the design of a controlled flooding scheme. We present the statistics of the time spent waiting at each intermediate, and we show that it could be of significant importance for forwarding.

The rest of this extended abstract is structured as follows. First, we describe the experimental data sets that have been used. Second, we present some results of characterization of paths in PSN. We conclude with general discussion on how we can use this work to propose an appropriate forwarding algorithm.

2. METHODOLOGY
We present here only results taken from the IEEE Infocom 2005 experimental data set. The results derived from others traces (Hong Kong city [2], IEEE Infocom 2006, etc.), will be added later for an upcoming paper.

During the week of IEEE Infocom 2005, we distributed 50 iMotes ("intel motes", which may be compared to the Berkeley Mote, and which contain a small processor, RAM and Bluetooth communication support) to a group of students attending the conference. Participants may be spanned across different social communities: students from the same laboratory, student from the same country, student working on the same research topic, etc. However, they all attend the same event for four consecutive days.

After the experiment, motes that have been collecting periodically the history of all contacts made during this week are brought back for the analysis of their content. This builds a collection of contacts between nodes, with a certain time label, that can be interpreted as a temporal network. A chronological path may be drawn on this graph between a source and a destination, going through intermediate nodes, following a sequence of contacts with increasing time order. For more details on this graph see [1].

2.1 Number of hop metrics
As described in [1] a small number of hops (4 hops in this trace) are generally enough to find an optimal path, in term of delay, almost at any time, for all sources and destinations. This was established by comparing the delivery success rate and the delay distribution obtained with/without a limiting number of hops set to 4. Both measures remain almost unchanged at any time scale.

This observation can be compared to the "small world phenomenon" observed in a social network. It indicates that an efficient path (short in delay as well as in hop) almost always exist to forward data between two nodes in PSN, but it does not provide a decentralized algorithm (except an exhaustive flooding technique) to find this path. In the rest of this extended abstract we report on some early results on a more detailed analysis of these paths.

2.2 Waiting time metrics

Flooding is costly in mobile networks, even if one limits the number of hops to 4 or 6, because the number of paths increases exponentially as nodes meet. At the same time it is usually not necessary because the set of interesting paths could be small.

Implementing a maximum waiting time at each step, at which the packet is dropped by the intermediate nodes, is one way to improve the control of flooding. Moreover, a regression implemented jointly between time and hop count reduces the number of packets: only the intermediate nodes that are present as a first or second hop may keep a copy of the packet for a long time, these nodes are usually less than those that may serve as a third or four hops.

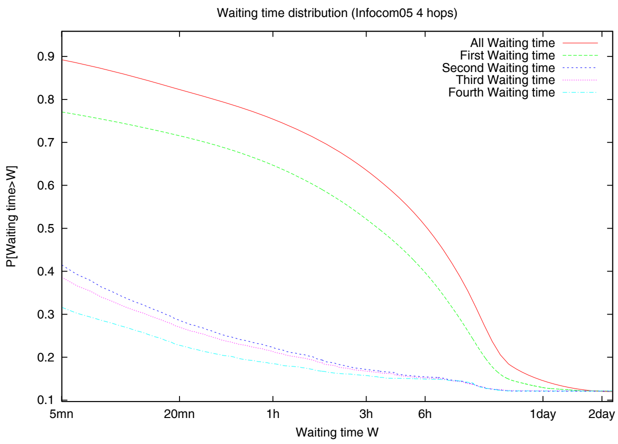

Figure 1: Waiting time distribution

To choose a best threshold values, we compute the first, second, third and fourth waiting time marginal distributions obtained in delay-optimal paths with less than 4 hops. (By convention, the waiting time at hop *i* is zero if the path uses fewer than *i* hops.)

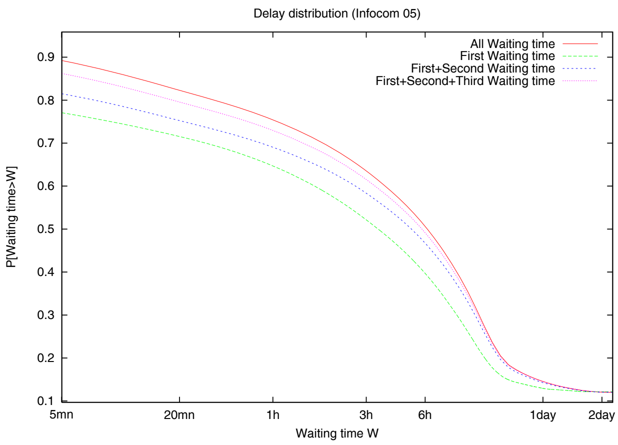

Figure 2: Cumulative waiting time distribution

As can be seen in Figure 1, the waiting time distribution varies in function of the position in the path: the CCDF of the first waiting time is by far the greatest and the difference between the first and others waiting time distributions is important at all timescales. We observe, for all hops except the first, that very few values lie between three hours and 1 day.

The distributions for the cumulative waiting times since the departure is shown in Figure 2. What we observe is that the effect of the third of fours hops is almost impossible to detect at larger timescale (above 3 or 6 hours). Again this indicates that most of the time we could strictly limit the amount of time spent in an intermediate nodes as hops increase,

Others results, including maximum and mininum waiting time in a path have been obtained but could not be reported here.

3. CONCLUSION

This paper contributes to characterize the set of delay-optimal paths observed between human carried devices. The structural properties of these paths are of a great interest for forwarding in PSN. As an example, we have shown that marginal distributions of the waiting times observed at each intermediate hops justify to implement a regression algorithm jointly with hop and time.

In future work, we will analyze other data sets and discuss the impact of infrastructure and density in PSN. Moreover, we propose to design an appropriate forwarding algorithm using TTL regression concept and other information (social relationship, infrastructure, density, etc.) to transfer data to an appropriate endpoint.

4. REFERENCES

[1] A. Chaintreau, P. Hui, J. Crowcroft, C. Diot, R. Gass, and J. Scott. Pocket switched networks: Real-world mobility and its consequences for opportunistic forwarding. Technical Report UCAM-CL-TR-617, University of Cambridge, Computer Laboratory, February 2005.

[2] A. Chaintreau, P. Hui, J. Crowcroft, C. Diot, R. Gass, and J. Scott, "Impact of human mobility on the design of opportunistic forwarding algorithms," in Proceedings of IEEE INFOCOM, 2006.

[3] S. J. Rahul C Shah, Sumit Roy and W. Brunette, "Data mules: Modeling a three-tier architecture for sparse sensor network," in IEEE Workshopon Sensor Network Protocols and Applications (SNPA), May 2003.

[4] M. A. Wenrui Zhao and E. Zegura, "A message ferrying approach for data delivery in sparse mobile ad hoc networks," in ACM Mobihoc, May 2004.

[5] M. McNett and G. M. Voelker. Access and mobility of wireless pda users. Technical report, Computer Science and Engineering, UC San Diego, 2004.

[6] T. Henderson, D. Kotz, and I. Abyzov. The changing usage of a mature campus-wide wireless network. In Proceedings of ACM Mobicom, 2004.

[7] W. Zhao and M. Ammar. Message ferrying: Proactive routing in highly-partitioned wireless ad hoc networks. In IEEE Workshop on Future Trends in Distributed Computing Systems, May 2003.